INSTITUTION NOTES

June, 1941

Re-arrangement of Publications.

It has been decided to issue a new publication, to be known as "The Technical Bulletin." In view of this, *The Bulletin*, hitherto issued with *The Journal*, is being discontinued, and usual notes formerly appearing therein will in future be incorporated each month in *The Journal*, except that notes on technical subjects will appear in *The Technical Bulletin*.

Death of Lord Austin (Hon. Member.)

The death of our distinguished Past-President, Lord Austin, in his 75th year, on May 23, marks the passing of a national figure who did much to further the growth of the Institution. He was President for the two years 1931-1933, but for years before then, and till 1939, attended and spoke at all Annual Dinners of the Institution and remained a member of Council for ten years up to the date of his death. He took a keen interest in the proposal to establish the Institution's Research Department. His Company was one of the first to give the Institution a subscription of £250 for research. He also arranged for an annual prize for the candidate with the highest attainments at the Graduateship Examination. The Institution was represented at the funeral by the General Secretary, and a wreath was forwarded on behalf of the Council.

New Honour for Lord Nuffield (Member)..

It is announced in the King's Birthday Honours List that the distinction of G.B.E. is being conferred on Viscount Nuffield for public services.

Newly Elected Members.

Members :

F. G. Child—The Incandescent Heat Co. Ltd., Birmingham.
E. H. L. Cooper—British Thomson Houston Co. Ltd., Rugby.

Associate Members :

L. Chubb—Thomas & Clement, Ltd., Llanelly.
F. W. Clegg—C. O. Ericsson Engineering Works, Ltd., Birmingham.
S. R. Cook—A. C. Wickman, Ltd., Coventry.
S. Dowling—Hydraulic Engineering Co. Ltd., Chester.
F. Hartop (Jnr.)—Frank Hartop & Sons, Ltd., Bedford.
T. A. Hartop—Frank Hartop & Sons, Ltd., Bedford.

Associate Members—contd.
F. L. Smith—Rolls-Royce, Ltd., Crewe.
T. W. Stacey—Knowles, Ltd., Bradford.
J. S. Waring—Municipal Technical School, Lurgan, Co. Armagh.
R. Waton—Cordes (Dos Works), Ltd., Newport.
T. B. Whitehouse—The Yale & Towne Manufacturing Co., Willenhall, Staffs.

Intermediate Associate Members :
H. Armitage—Rolls-Royce, Ltd., Crewe.
E. Charnley—Royal Ordnance Factory, Radcliffe.
G. A. Cleary—Wilson & Mathieson, Ltd., Leeds.
C. G. Crowley—Humber, Ltd., Coventry.
F. G. Davies—E.M.B. Co. Ltd., West Bromwich.
T. W. Guthrie—Messrs Brown Bros (Aircraft), Ltd.
H. F. Loftin—Harris Lebus, Tottenham.
W. F. Shelton—Hoover, Ltd., Perivale, Middlesex.
J. Townsend—Bradley & Craven, Ltd., Wakefield.
L. G. T. Williams—Hall Telephone Accessories (1928), Ltd., Dowlais, Glam.

Graduates :
K. C. Bairstow—The English Electric Co. Ltd., Bradford.
T. A. Macaulay—The English Electric Co. Ltd., Bradford.
D. H. Mills—Sir W. G. Armstrong Whitworth Aircraft, Ltd.
D. H. Milnes—Messrs. Metalclad, Ltd., Neath, Glam.
F. Neale—The Brooke Tool Manufacturing Co. Ltd., Birmingham.
E. G. A. Smith—Dinsdale Engineering Co. Ltd.

Students :
K. R. V. Bryant—25, Branksome Avenue, Bridfort Road, Edmonton, N.18.
S. Evans—" Someries," 8, Church Lane, Darley Abbey, Derby.
R. Pope—10, Wade Avenue, Littleover, Derby.
F. L. Smith—6, Cobden Road, Chatham, Kent.
W. T. Vaughan—33, Pipers Row, Wolverhampton, Staffs.

Transfers.

From Associate Member to Ordinary Member :
R. L. Scott—MacTaggart, Scott & Co. Ltd., Loanhead, Midlothian.
W. N. Meacham—Villiers Engineering Co. Ltd., Wolverhampton.

From Intermediate Associate Member to Associate Member :
R. Wake—D. Napier & Son, Ltd., Liverpool.

From Graduate to Associate Member :
F. Cotton—Coventry Climax Engines, Coventry.

From Student to Graduate :
H. G. Shakeshaft—C. A. V. Ltd., Acton.

Utilisation and Training of Labour.

Mr. B. C. Jenkins, (Member), Member of Council, Chief Inspector of Munitions Labour Supply, Ministry of Labour and National Service, has now read his paper on "The Utilisation and Training of Labour under War Conditions" to the following nine Local Sections of the Institution: Luton, January 19; London, February 28; Cornwall, March 5; Yorkshire, March 15; Leicester, April 3; Western, April 26; Newcastle, May 3; Coventry, May 20; Birmingham, May 21. The paper, together with a report of the various Discussions, will be published in *The Journal*.

Local Section Activities.

The Preston Section held a well-attended dinner, followed by an interesting Informal Discussion on May 22. It is intended to hold similar gatherings throughout the summer months.

The Nottingham Section is arranging a summer programme to include a social function and visits to Works.

The Manchester Section had a successful meeting on May 26, when Mr. Mark H. Taylor gave a paper on "The Application of Optics to Engineering." The attendance numbered about 90 members and visitors.

The Sheffield Section held a luncheon at the Royal Victoria Station Hotel, Sheffield, on May 29, attended by over 70 members and visitors. The speaker on the occasion was Mr. R. Hazleton, General Secretary.

The Yorkshire Section foregathered on June 12 for a re-union, which concluded with a supper.

The Leicester and District Section has been co-operating with the Leicester College of Technology in framing a syllabus for a Production Engineering Course at the College.

The Sydney Section has arranged a full programme of lectures for its coming session. It has recently had its Annual Works Visit, which was to the Small Arms Factory, Lithgow.

The Luton, Bedford and District Section reports with regret the death of Mr. F. Brown, who has been for years a valued member of the Section Committee.

Mr. R. M. Buckle succeeds Mr. H. W. Smith as Section Hon. Secretary, Mr. Smith having taken up a position in the North of England.

Programme for Next Session.

Local Section Committees are now engaged in arranging their programme of lectures for next session. Members who may be in a position to offer papers for consideration are kindly requested to notify London Headquarters or the Hon. Secretary of their Local Section.

Work of the War Emergency Committee.

(*a*) *Technical and Publications Committee.* The new Technical and Publications Committee, the formation of which has been previously announced, is now functioning actively and has already held several meetings. Its Chairman is Mr. W. Puckey.

(*b*) *New National Production Committee.* A letter was addressed recently by the President of the Institution, Mr. Bailey, to the Federation of British Industries with the object of encouraging that body, which is looked to by the Government to represent the views of industry, to set up a War Production Committee, as it was felt that the Federation might possibly present industry's views on production problems with a stronger voice than could be done by our Institution alone. The proposal was actively taken up by the F.B.I., who have now, in fact, formed a War Production Committee, and have written to Mr. N. V. Kipping, Chairman of our War Emergency Committee, inviting him to become a member. The Institution, through its War Emergency Committee, is thus ensured of a voice in the work of this new and important Committee, whose aim will be to assist in the solution of war-time production problems.

(*c*) *Designing for Production.* The Institution's advisory work in this matter has continued, particularly in relation to light alloy forgings for aircraft. Further meetings have taken place at which representatives of the Institution have advised on specific design problems which have been submitted. Mr. J. E. Blackshaw has been very active in this work, which has taken place through the Director of Aircraft Development.

(*d*) *Central Register.* The Institution has been represented by Mr. G. H. Hales at recent meetings of the General Engineering Committee and the Mechanical Engineering Sub-Committee of the Central Register. He has not been able to report favourably on the progress made.

Subscriptions.

Subscriptions for the Institution's financial year 1941-42 become due on July 1.

Research Department of the Institution.

REPORT ON THE CORRECT DESIGN AND EFFICIENCY OF TAPS.

By Dr. Geo. Schlesinger, Director of Research.

Introduction.

A GREAT deal of research work has been done in connection with the machineability of materials by turning, milling and drilling. From the data thus obtained, rules have been formulated from which may be determined the cutting angles on the tools, depth of cut, feed and cutting speed to enable a particular component to be machined in the most economical manner.

The governing factor when investigating these methods of machining has usually been the quickest way of reducing the workpiece to the required dimensions, and such considerations as quality of surface, finish, and accuracy of dimensions have been of secondary importance. Most cutting tests are concerned with the best roughing or semi-finishing conditions, and little reliable data is available as regards finishing and fine finishing. Such operations are usually carried out by using secondary machining methods, such as diamond turning, grinding, lapping or honing and depend for the most part on the accuracy of the machine tool, together with rigid, correctly ground tools using a small depth of cut, fine feed and fast-cutting speed.

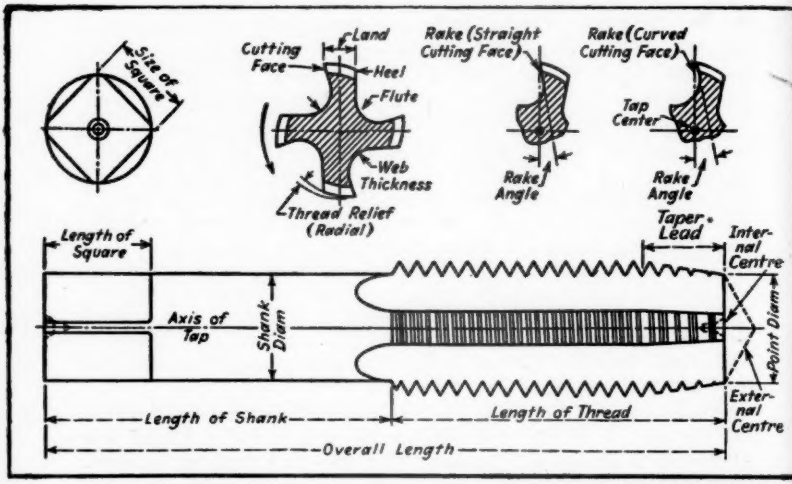
When machining internal and external threads, however, which call for the use of taps and dies, accuracy of shape to within fine tolerances is demanded, together with smoothly finished surfaces. In most cases a second operation to finish a thread made by a tap or die is not possible for reasons of economy.

Fig. 1 shows a standard tap and indicates the various terms used. The feed is given by the pitch of the thread. The shape of the thread (B.S.W., U.S.S., I.S.A., etc.) is fixed and determines the depth of cut and the only variable is the cutting speed. Cutting angles must be adapted to the material being threaded, but this adaptability is much more limited than with ordinary single or multi-point cutting tools. With a tap or a die all the work is done in one single pass, because the tool contains all the necessary dimensions. Indeed, the whole work of the tap or die is done by the chamfer (or taper lead) at the front and the first or second

threads following this chamfer, these threads being in effect the finishing part of the tool. Because the feed is controlled by the pitch of the thread and the section of the chip by its profile, the stress on the cutting edges of the chamfer can only be regulated by varying the length of this chamfer or by changing the cutting speed. Another method of reducing the tool stress is by distributing the work between two, three or more taps in a set.

The Selection of the Correct Type of Tap

It is usual to finish a thread, where possible, in one operation, for reasons of economy. This being so, the chamfer (taper lead) on the tap should be made long enough to ensure a good distribution



* taper lead or chamfer

Fig. 1. Views of a standard tap indicating the descriptive terms employed.

of the cutting forces. The machine nut tap or tapper tap, Fig. 2, embodies this feature. The possibility of using this tap is limited by the fact that the run out of the thread is often limited, as in blind holes, and is, therefore, smaller than the chamfer on the tap.

As stated above, the load is well distributed. The work done in one turn of the tap produces one finished thread. With a long chamfer, each cutting edge is lightly loaded and the tap will have long life. Tapper taps frequently have more than one nut on the chamfer at one time.

In most cases it is necessary to shorten the chamfer. The machine nut tap with the shortened chamfer becomes the so-called machine tap, and an example is shown in Fig. 3. This tap may be used to

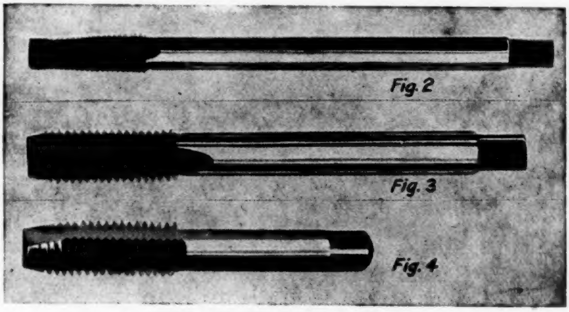


Fig. 2. Machine nut tap or tapper tap.
Fig. 3. Machine tap with reduced length of chamfer.
Fig. 4. A single cutting tap with shaving chamfer.

cut threads when the run-out is short. Its usefulness is limited by the machineability of the material, and it may be necessary to sub-divide the operation between a set of taps.

The single cutting tap in Fig. 4 has a chamfer giving a shaving cut for threads which are longer than those of the ordinary nut.

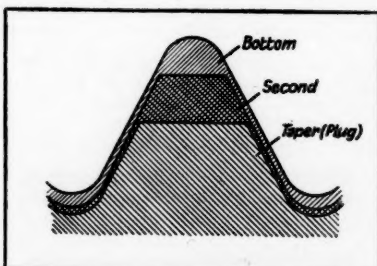


Fig. 5. Diagram showing how the total cut can be divided between three taps of a set.

These taps are very efficient and are eminently suitable for machine tapping operations on through holes.

One method of stepping a set of three taps on the flanks and depth of thread is shown in Fig. 5 (see Fig. 13); in addition the lengths of the chamfers are varied. For through holes taps with

longer chamfers can be used than for blind holes. Consequently, the sub-division into two taps, as in Fig. 6, is often sufficient, whilst

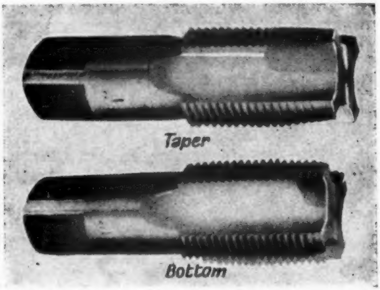


Fig. 6. A set of two hand taps.

for blind holes three or more taps may be necessary, Fig. 7. The bottom tap should have only one thread chamfered. Thus, for ordinary machine taps we have the following divisions :—

(1) Nut taps for short through holes, the lengths of which are not greater than those of standard nuts.

(2) Machine taps for long through holes in material which is easily cut, or where a long run-out is not permissible.

(3) Set of two taps for through holes even for materials, difficult to machine.

(4) Set of three or more taps for materials difficult to machine or for holes with short run-out.

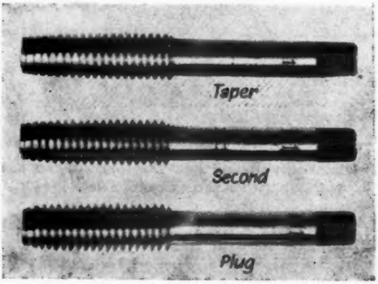


Fig. 7. A set of three hand taps.

Ground Thread Taps.

By grinding all essential parts of the taps after hardening, on their own centres, ground taps are made accurately straight and concentric. They have correctly shaped flutes to give the best cutting action, and power consumption is reduced. In addition, the largest possible chip chamber is obtained without weakening the tap to any appreciable extent.

The British Standard Institution have published in B.S. No. 949 (temporary issue) of April, 1941, new tolerances for the diameters, pitches and angles of screwing taps.

TOLERANCES ON EFFECTIVE DIAMETER (Table I). It will be noted that the tolerance on effective diameter is based upon the cube root of the major diameter. This conforms with general manufacturing experience.

TOLERANCES ON CUMULATIVE PITCH ERROR (Table II). The tolerances allowed on the cumulative pitch errors of taps are based on a length of thread of 1 in. The tolerances for the four grades of taps are—

Ground threads, Grade 1	...	0.0003 in. over a 1-in. length
,, ,, Grade 2	...	0.0006 ,, ,, ,,
Cut threads, Grade 1	...	0.0015 ,, ,, ,,
,, ,, Grade 2	...	0.003 ,, ,, ,,

In order to arrive at corresponding tolerances for lengths other than 1 in., it was borne in mind that, in general, the error in the pitch of a screw thread does not accumulate in direct proportion to the length of the thread, but more in proportion to the square root of the length. It was decided, therefore, that the tolerances which should be allowed on taps having a length of thread represented by L inches, should be obtained by multiplying the above tolerances on the unit length by $\sqrt{L}$. Table I gives the tolerances on the cumulative pitch error for any length of thread between $\frac{1}{4}$ in. and 5 in. for each of the four threads between $\frac{1}{4}$ in. and 5 in. for each of the four grades of taps.

TOLERANCE ON ANGLE. In order to exercise control over the symmetry of the thread as well as over the total angle of the thread, the tolerances given in the tables for angle are to be regarded as the maximum permissible sum of the errors in the two flank angles of a tap thread disregarding their signs.

These tolerances of ground taps can be made smaller, if desired. The pitch and effective diameter tolerances ensure flank contact of thread between nut and bolt and complete interchangeability. The greatest possible accuracy in this connection is obtained by using taps ground on the thread after hardening. The cutting threads of taps are relieved on the entire profile whereby good cutting capacity

*TABLE I.—FORMULAE FOR LIMITS AND TOLERANCES ON TAPS FOR THREADS OF WHITWORTH FORM
B.S. WHITWORTH, B.S. FINE, AND B.S. PIPE, PARALLEL

		Diametral limits expressed as amounts over basic size				Minor dia.	Tolerance on cumulative pitch error	Tolerance on angle
		Major dia.		Effective dia.				
		Max.	Min.	Max.	Min.			
Hand taps, and pearn tapper taps	Ground 1 ...	Not specified	$1\frac{1}{2}$ A	$A + 0.001\sqrt[3]{D}$	A	Tol'ce = $1\frac{1}{2}$A plus twice the effective dia. tolerance.	$0.0003\sqrt{L}$	$\frac{0.25}{\sqrt{p}}$
	Ground 2 ...	Ditto	$1\frac{1}{2}$ A	$A + 0.002\sqrt[3]{D}$	A		$0.0006\sqrt{L}$	$\frac{0.4}{\sqrt{p}}$
	Cut 1 ...	Ditto	$1\frac{1}{2}$ A	$A + 0.0025\sqrt[3]{D}$	A	Dispos'd 80% above basic, 20% below basic.	$0.0015\sqrt{L}$	$\frac{0.4}{\sqrt{p}}$
	Cut 2 ...	Ditto	$1\frac{1}{2}$ A	$A + 0.004\sqrt[3]{D}$	A		$0.003\sqrt{L}$	$\frac{0.5}{\sqrt{p}}$
Nut taps	Ground ...	Ditto	$2\frac{3}{4}$ A	$2A + 0.002\sqrt[3]{D}$	2A		$0.0006\sqrt{L}$	$\frac{0.4}{\sqrt{p}}$
	Cut ...	Ditto	$2\frac{3}{4}$ A	$2A + 0.0025\sqrt[3]{D}$	2A		$0.0015\sqrt{L}$	$\frac{0.4}{\sqrt{p}}$

D = basic major diameter in inches. L = length of thread in inches. p = pitch in inches.
A = an allowance for wear. It is equal to 0.0008 D plus 0.0006, and has the following values.

B.S.W. / B.S.F. Nom. dia. .	$\frac{1}{8}$	$\frac{3}{16}$ $\frac{7}{32}$ $\frac{1}{4}$ $\frac{9}{32}$ $\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$ $\frac{1}{2}$ $\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$ $\frac{3}{4}$ $\frac{13}{16}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	—	$1\frac{3}{4}$	—	2
B.S.P. size ...			$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	—	$\frac{1}{2}$ $\frac{5}{8}$	$\frac{3}{4}$	—	$\frac{7}{8}$ 1	—	—	$1\frac{1}{4}$	—	$1\frac{1}{2}$	—
A (0.001 in.) ...	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2

*Tables I to VI communicated by the British Standards Institution.

TABLE II.—TOLERANCES ON CUMULATIVE PITCH ERROR

B.S. WHITWORTH, B.S. FINE, B.S. PIPE (PARALLEL), AND B.A.

1	2	3	4	5	6	7	8
Length of thread		Hand taps and Pearn tapper taps				Nut taps	
		Ground thread		Cut thread			
From	To and including	Grade I	Grade II	Grade I	Grade II	Ground thread	Cut thread
In.	In.	In.	In.	In.	In.	In.	In.
1/4	1/2	0.0002	0.0004	0.0009	0.0018	0.0004	0.0018
1/2	3/4	0.0002	0.0005	0.0012	0.0024	0.0005	0.0024
3/4	1	0.0003	0.0006	0.0014	0.0028	0.0006	0.0028
1	1 1/4	0.0003	0.0006	0.0016	0.0032	0.0006	0.0032
1 1/4	1 1/2	0.0004	0.0007	0.0018	0.0035	0.0007	0.0035
1 1/2	1 3/4	0.0004	0.0008	0.0019	0.0038	0.0008	0.0038
1 3/4	2	0.0004	0.0008	0.0021	0.0041	0.0008	0.0041
2	2 1/4	0.0004	0.0009	0.0022	0.0044	0.0009	0.0044
2 1/4	2 1/2	0.0005	0.0009	0.0023	0.0046	0.0009	0.0046
2 1/2	2 3/4	0.0005	0.0010	0.0024	0.0049	0.0010	0.0048
2 3/4	3	0.0005	0.0010	0.0025	0.0051	0.0010	0.0051
3	3 1/2	0.0005	0.0011	0.0027	0.0054	0.0011	0.0054
3 1/2	4	0.0006	0.0012	0.0029	0.0058	0.0012	0.0058
4	4 1/2	0.0006	0.0012	0.0031	0.0062	0.0012	0.0062
4 1/2	5	0.0007	0.0013	0.0033	0 0065	0.0013	0.0065

*Tables I to VI communicated by the British Standards Institution.

is ensured, and any tendency to stick in the work material is obviated. When these taps have been used on soft material, it has been ascertained that the metal does not " pick up " on the tap. The relief of taps is dimensioned in relation to their oversize ; so that it is theoretically possible to sharpen away the whole width of the land without the diameter of the tap becoming less than the nominal size. The amount of relief varies, and depends among other factors upon the shape of the thread, the purpose for which the taps are intended, and the class of material to be tapped.

The tendency now is to reduce the relief on the threads. Taps of $\frac{1}{4}$ in. diameter and under have no relief on the threads and a minimum of relief on the chamfer. Better control of size tapping is thus obtained. (Although the grinder is set for no relief, the thrust of the grinding wheel against the land in plunge grinding may give 0.0001 in. relief per land.)

The Shape of the Tap

Referring again to Fig. 1, of special importance are the number of flutes and the shape thereof, the length and shape of the chamfer, and the angle and shape of the rake. A nut tap, as in Fig. 2, is designed for use in machine shops, where nuts are tapped from black or bright material bored to the minor or core diameter. It is customary practice to provide the entering threads, for approximately 75% of the thread length, with a slight taper on both pitch (effective) diameter and root diameter to ensure tapping a nut with a full form of thread. The length overall, length of thread and length of shank are much greater than on a normal hand tap.

The body of the tap has a slight axial relief, known as back taper, with the result that the pitch diameter of the thread near the shank is somewhat smaller than at the point.

The taper formed at the end of the tap by cutting away the crests of the first few threads is called the chamfer or lead-in. The object is to distribute the cutting action over several teeth, and the taper also acts as a guide in starting the tap in a hole.

The major diameter is commonly known as the outside or full diameter. On a straight tap the major diameter is the largest diameter of the thread on the tap.

The minor diameter is commonly known as the core or root diameter. On a straight tap the minor diameter is the smallest diameter of the thread on the tap.

Rake is the hook or undercut on the face of the lands. When the faces are radial, the rake angle is zero. The rake angle is positive, when the outer edge of the land is ahead of the root. The rake angle is varied for different materials and conditions of tapping. Relief is obtained by removing metal from behind the cutting edge to produce clearance and reduce friction. Taps should be relieved

over the chamfered portion and may, or may not, have relief in the angle and on the major diameter of the threads.

Tolerances.

The B.S.I. Standards for B.S.W., B.S.F. and B.S.P. bolts and nuts distinguish between close, medium and free fits and give the tolerances to which the work-pieces must be finished, but in the latest preliminary issue, B.S. No. 949/1941 tolerance tables are given for the manufacturing accuracy of the taps themselves. It seems to be more practical (see also the American Standards for taps) to distinguish the taps by their method of manufacture, i.e. whether cut or ground, because the accuracy of the tap has a decisive effect upon the quality of the fit (close, medium or free) Tables (III and IV) give the proposed limits and tolerances for B.S.W. hand taps and tapper taps, grades (1) and (2), with ground threads, and tables V and VI for grades 1 and 2 taps with cut threads. For B.S. Fine, B.S. Pipe and B.A. taps similar tolerance tables have been drawn up. For the nut taps of all systems only two grades are established, one for ground and one for cut taps.

For the major diameters of both cut and ground taps only one minimum dimension is fixed.

In Table VII the American standard dimensions are given for a 1-in. diameter tap and screw gauge No. 12 tap as examples. The tolerances vary from 0.0030 to 0.0005 in. for the effective diameter of hand taps to 0.0015 to 0.0005 in. for machine taps. These, and the manufacturer's tolerances on British taps, are considerably smaller than for the corresponding British B.S.W. nuts, namely, 0.0045 in. (close) and 0.0066 in. (medium) tolerances.

The American standards allow 0.0005 in. pitch tolerance in 1 in. of thread length for ground taps, whereas the first-class British manufacturers allow 0.0003 in. per in. over the threaded portions of grade 1 ground taps and 0.0006 in. per in. for grade 2 ground taps.

As stated, the B.S.I. Standards* provide for three classes of fits for internal threads (nuts) :—

(*a*) close fit ;

(*b*) medium fit ;

(*c*) free fit, for commercial use.

For high-class work (e.g. aircraft and aero engines), where a bolt which becomes loose may be a source of danger, close fits are used ; while medium fits suffice for ordinary good machinery work.

The nominal basic size represents the lower limit for the nut for all grades of fit. The tolerances for the B.S.W. and B.S.F. series are calculated for a length of engagement equal to the nominal

TABLE III.—LIMITS AND TOLERANCES FOR B.S.W. HAND TAPS AND PEARN TAPPER TAPS

GRADE I—GROUND THREAD

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal dia.	No. of threads per inch	Major diameter		Effective diameter				Minor diameter				Tolerance on angle
		Basic	Min.	Basic	Max.	Tol.	Min.	Basic	Max.	Tol.	Min.	
In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Deg.
1/8	40	0.1250	0.1259	0.1090	0.1102	0.0005	0.1097	0.0930	0.0946	0.0020	0.0926	1.6
3/16	24	0.1875	0.1886	0.1608	0.1622	0.0006	0.1616	0.1341	0.1360	0.0024	0.1336	1.2
1/4	20	0.2500	0.2510	0.2180	0.2194	0.0006	0.2188	0.1860	0.1879	0.0024	0.1855	1.1
5/16	18	0.3125	0.3136	0.2769	0.2784	0.0007	0.2777	0.2413	0.2434	0.0026	0.2408	1.1
3/8	16	0.3750	0.3762	0.3350	0.3367	0.0007	0.3359	0.2950	0.2972	0.0028	0.2944	1.0
7/16	14	0.4375	0.4388	0.3918	0.3936	0.0008	0.3928	0.3461	0.3486	0.0031	0.3455	0.9
1/2	12	0.5000	0.5013	0.4466	0.4484	0.0008	0.4476	0.3932	0.3957	0.0031	0.3926	0.9
9/16	12	0.5625	0.5638	0.5091	0.5109	0.0008	0.5101	0.4557	0.4582	0.0031	0.4551	0.9
5/8	11	0.6250	0.6265	0.5668	0.5688	0.0009	0.5679	0.5086	0.5113	0.0034	0.5079	0.8
11/16	11	0.6875	0.6891	0.6293	0.6314	0.0009	0.6305	0.5711	0.5740	0.0036	0.5704	0.8
3/4	10	0.7500	0.7516	0.6860	0.6881	0.0009	0.6872	0.6220	0.6249	0.0036	0.6213	0.8
7/8	9	0.8750	0.8767	0.8039	0.8062	0.0010	0.8052	0.7328	0.7360	0.0040	0.7320	0.8
1	8	1.0000	1.0019	0.9200	0.9224	0.0010	0.9214	0.8400	0.8433	0.0041	0.8392	0.7
1 1/8	7	1.1250	1.1270	1.0335	1.0360	0.0010	1.0350	0.9420	0.9454	0.0042	0.9412	0.7
1 1/4	7	1.2500	1.2521	1.1585	1.1612	0.0011	1.1601	1.0670	1.0707	0.0046	1.0661	0.7
1 1/2	6	1.5000	1.5024	1.3933	1.3962	0.0011	1.3951	1.2866	1.2905	0.0049	1.2856	0.6
1 3/4	5	1.7500	1.7527	1.6219	1.6251	0.0012	1.6239	1.4938	1.4981	0.0054	1.4927	0.6
2	4.5	2.0000	2.0029	1.8577	1.8612	0.0013	1.8599	1.7154	1.7201	0.0059	1.7142	0.5

TABLE IV.—LIMITS AND TOLERANCES FOR B.S.W. HAND TAPS AND PEARN TAPPER TAPS

GRADE II—GROUND THREAD

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal diameter	No. of threads per inch	Major diameter		Effective diameter				Minor diameter				Tolerance on angle
		Basic	Min.	Basic	Max.	Tol.	Min.	Basic	Max.	Tol.	Min.	
In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Deg.
1/8	40	0.1250	0.1259	0.1090	0.1107	0.0010	0.1097	0.0930	0.0954	0.0030	0.0924	2.5
3/16	24	0.1875	0.1886	0.1608	0.1627	0.0011	0.1616	0.1341	0.1368	0.0034	0.1334	2.0
1/4	20	0.2500	0.2511	0.2180	0.2201	0.0013	0.2188	0.1860	0.1890	0.0038	0.1852	1.8
5/16	18	0.3125	0.3136	0.2769	0.2791	0.0014	0.2777	0.2413	0.2445	0.0040	0.2405	1.7
3/8	16	0.3750	0.3762	0.3350	0.3373	0.0014	0.3359	0.2950	0.2984	0.0042	0.2942	1.6
7/16	14	0.4375	0.4388	0.3918	0.3943	0.0015	0.3928	0.3461	0.3497	0.0045	0.3452	1.5
1/2	12	0.5000	0.5013	0.4466	0.4492	0.0016	0.4476	0.3932	0.3970	0.0047	0.3923	1.4
9/16	12	0.5625	0.5638	0.5091	0.5118	0.0017	0.5101	0.4557	0.4596	0.0049	0.4547	1.4
5/8	11	0.6250	0.6265	0.5668	0.5696	0.0017	0.5679	0.5086	0.5126	0.0050	0.5076	1.3
11/16	11	0.6875	0.6891	0.6293	0.6323	0.0018	0.6305	0.5711	0.5754	0.0054	0.5700	1.3
3/4	10	0.7500	0.7516	0.6860	0.6890	0.0018	0.6872	0.6220	0.6263	0.0054	0.6209	1.3
7/8	9	0.8750	0.8767	0.8039	0.8071	0.0019	0.8052	0.7328	0.7374	0.0058	0.7216	1.2
1	8	1.0000	1.0019	0.9200	0.9234	0.0020	0.9214	0.8400	0.8449	0.0061	0.8388	1.1
1 1/8	7	1.1250	1.1270	1.0335	1.0371	0.0021	1.0350	0.9420	0.9471	0.0064	0.9407	1.1
1 1/4	7	1.2500	1.2521	1.1585	1.1623	0.0022	1.1601	1.0670	1.0724	0.0068	1.0656	1.1
1 1/2	6	1.5000	1.5024	1.3983	1.3974	0.0023	1.3951	1.2866	1.2924	0.0073	1.2951	1.0
1 3/4	5	1.7500	1.7527	1.6219	1.6263	0.0024	1.6239	1.4938	1.5000	0.0078	1.4922	0.9
2	4.5	2.0000	2.0029	1.8577	1.8624	0.0025	1.8599	1.7154	1.7220	0.0083	1.7137	0.8

TABLE V.—LIMITS AND TOLERANCES FOR B.S.W. HAND TAPS AND PEARN TAPPER TAPS

GRADE I—CUT THREAD

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal diameter	No. of threads per inch	Major diameter		Effective diameter				Minor diameter				Tolerance on angle
		Basic	Min.	Basic	Max.	Tol.	Min.	Basic	Max.	Tol.	Min.	
In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Deg.
1/8	40	0.1250	0.1259	0.1090	0.1109	0.0012	0.1097	0.0930	0.0957	0.0034	0.0923	2.5
3/16	24	0.1875	0.1886	0.1608	0.1630	0.0014	0.1616	0.1341	0.1373	0.0040	0.1333	2.0
1/4	20	0.2500	0.2510	0.2180	0.2204	0.0016	0.2188	0.1860	0.1895	0.0044	0.1851	1.8
5/16	18	0.3125	0.3136	0.2769	0.2794	0.0017	0.2777	0.2413	0.2450	0.0046	0.2404	1.7
3/8	16	0.3750	0.3762	0.3350	0.3377	0.0018	0.3359	0.2950	0.2990	0.0050	0.2940	1.6
7/16	14	0.4375	0.4388	0.3918	0.3947	0.0019	0.3928	0.3461	0.3503	0.0053	0.3450	1.5
1/2	12	0.5000	0.5013	0.4466	0.4496	0.0020	0.4476	0.3932	0.3976	0.0055	0.3921	1.4
9/16	12	0.5625	0.5638	0.5091	0.5122	0.0021	0.5101	0.4557	0.4603	0.0057	0.4546	1.4
5/8	11	0.6250	0.6265	0.5668	0.5700	0.0021	0.5679	0.5086	0.5132	0.0058	0.5074	1.3
11/16	11	0.6875	0.6891	0.6293	0.6327	0.0022	0.6305	0.5711	0.5761	0.0062	0.5699	1.3
3/4	10	0.7500	0.7516	0.6860	0.6895	0.0023	0.6872	0.6220	0.6271	0.0064	0.6207	1.3
7/8	9	0.8750	0.8767	0.8039	0.8076	0.0024	0.8052	0.7328	0.7382	0.0068	0.7314	1.2
1	8	1.0000	1.0019	0.9200	0.9239	0.0025	0.9214	0.8400	0.8457	0.0071	0.8386	1.1
1 1/8	7	1.1250	1.1270	1.0335	1.0376	0.0026	1.0350	0.9420	0.9279	0.0074	0.9405	1.1
1 1/4	7	1.2500	1.2521	1.1585	1.1628	0.0027	1.1601	1,0670	1.0732	0.0078	1.0654	1.1
1 1/2	6	1.5000	1.5024	1.3933	1.3980	0.0029	1.3951	1.2866	1.2934	0.0085	1.2849	1.0
1 3/4	5	1.7500	1.7527	1.6219	1.6269	0.0030	1.6239	1.4938	1.5110	0.0090	1.4920	0.9
2	4.5	2.0000	2.0029	1.8577	1.8631	0.0032	1.8599	1.7154	1.7232	0.0097	1.7135	0.8

TABLE VI.—LIMITS AND TOLERANCES FOR B.S.W. HAND TAPS AND PEARN TAPPER TAPS

GRADE II—CUT THREAD

1	2	3	4	5	6	7	8	9	10	11	12	13
Nominal diameter	No. of threads per inch	Major diameter		Effective diameter				Minor diameter				Tolerance on angle
		Basic	Min.	Basic	Max.	Tol.	Min.	Basic	Max.	Tol.	Min.	
In.		In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	Deg.
1/8	40	0.1250	0.1259	0.1090	0.1117	0.0020	0.1097	0.0930	0.0970	0.0050	0.0920	3.2
3/16	24	0.1875	0.1886	0.1608	0.1639	0.0023	0.1616	0.1341	0.1387	0.0058	0.1329	2.4
1/4	20	0.2500	0.2511	0.2180	0.2213	0.0025	0.2188	0.1860	0.1910	0.0062	0.1848	2.2
5/16	18	0.3125	0.3136	0.2769	0.2804	0.0027	0.2777	0.2413	0.2466	0.0066	0.2400	2.1
3/8	16	0.3750	0.3762	0.3350	0.3388	0.0029	0.3359	0.2950	0.3008	0.0072	0.2936	2.0
7/16	14	0.4375	0.4388	0.3918	0.3958	0.0030	0.3928	0.3461	0.3521	0.0075	0.3446	1.9
1/2	12	0.5000	0.5013	0.4466	0.4508	0.0032	0.4476	0.3932	0.3995	0.0079	0.3916	1.7
9/16	12	0.5625	0.5638	0.5091	0.5134	0.0033	0.5101	0.4557	0.4622	0.0081	0.4541	1.7
5/8	11	0.6250	0.6265	0.5668	0.5713	0.0034	0.5679	0.5086	0.5153	0.0084	0.5069	1.7
11/16	11	0.6875	0.6891	0.6293	0.6340	0.0035	0.6305	0.5711	0.5781	0.0088	0.5693	1.7
3/4	10	0.7500	0.7516	0.6860	0.6908	0.0036	0.6872	0.6220	0.6292	0.0090	0.6202	1.6
7/8	9	0.8750	0.8767	0.8039	0.8090	0.0038	0.8052	0.7328	0.7405	0.0096	0.7309	1.5
1	8	1.0000	1.0019	0.9200	0.9254	0.0040	0.9214	0.8400	0.8481	0.0101	0.8380	1.4
1 1/8	7	1.1250	1.1270	1.0335	1.0392	0.0042	1.0350	0.9420	0.9505	0.0106	0.9399	1.3
1 1/4	7	1.2500	1.2521	1.1585	1.1644	0.0043	1.1601	1.0670	1.0758	0.0110	1.0648	1.3
1 1/2	6	1.5000	1.5024	1.3933	1.3997	0.0046	1.3951	1.2866	1.2961	0.0119	1.2842	1.2
1 3/4	5	1.7500	1.7527	1.6219	1.6287	0.0048	1.6239	1.4938	1.5039	0.0126	1.4913	1.1
2	4.5	2.0000	2.0029	1.8577	1.8649	0.0050	1.8599	1.7154	1.7260	0.0133	1.7127	1.1

TABLE VII.—EXAMPLES OF AMERICAN STANDARD TOLERANCES FOR TAPS

Hand taps	Size in.	Threads per in.	Major diameter				Effective (pitch) diameter			
			Basic in.	Min. in.	Max. in.	Tol. in.	Basic in.	Min. in.	Max. in.	Tol. in.
Cut threads	1	8	1.000	1.0078	1.0118	0.0030	0.9188	0.9198	0.9228	0.0030
Commercial ground thread ...	1	8	1.000	1.0095	1.0110	0.0015	0.9188	0.9198	0.9212	0.0014
Precision ground thread ...	1	8	1.000	1.0095	1.0110	0.0015	0.9188	0.9193	0.9198	0.0005
Machine screw taps	Screw gauge No.	Threads per inch								
Cut thread	12	24	0.2160	0.2188	0.2208	0.0020	0.1889	0.1894	0.1909	0.0015
Commercial ground thread ...	12	24	0.2160	0.2190	0.2200	0.0010	0.1889	0.1894	0.1904	0.0010
Precision ground thread ...	12	24	0.2160	0.2190	0.2200	0.0010	0.1889	0.1889	0.1894	0.0005

LEAD TOLERANCE (American) cut-thread—a maximum lead error of $\pm$ 0.003 in. in one inch of thread is permitted.
Ground thread (commercial and precision)—a maximum lead error of $\pm$ 0.0005 in. in one inch of thread is permitted.

Angle tolerance (American)	Threads per inch	Error in half angle	Error in full angle
		Min.	Min.
Cut thread	20	± 45	68
Ground thread (commercial and precision) ...	20	± 30	—

diameter. The three grades of tolerance correspond to the following definitions :—

Close Fit.—This includes screw thread work requiring a fine and snug fit. It is only obtainable by the use of the highest quality screwing tools, supported by a very efficient system of gauging and inspection. This grade of fit is recommended only for special work, where refined accuracy of pitch and thread form are particularly required.

Medium Fit.—This includes the better grade of interchangeable screw thread work.

Free Fit.—This includes the great bulk of screw thread work of ordinary quality.

Effective Diameter Tolerances of Nuts.

Effective diameter tolerances include the effects of errors present in pitch and angle. For medium fit the effective diameter tolerance is derived from the formula :—

Effective diameter tolerance medium fit $= 0.002 \sqrt[3]{D} + 0.003 \sqrt{L} + 0.005 \sqrt{p}$. Where D = major (full) diameter of screw thread, L = length of engagement, p = pitch (all values in inches).

For the close fit, the formula is : $2/3 \times$ effective diameter tolerance medium fit.

No upper limit is stated for the major (outside) diameter of the nut for any of the three grades of fit. The tolerance of the minor (core) diameter of the nut is the same for all grades of fit. The tolerance is such as to permit of using a tapping drill of ample size to prevent binding at the core diameter of the tap. Tables VIII and IX show the different tap drill sizes.

Table VIII gives drills which have been obtained by taking the nearest B.S.I. standard drill size to the nominal core diameter.

Table IX gives tap drill sizes which allow for the thread in tapped holes to be from 70 to 80% of full depth. This permits easy tapping and reduces the strain on the tap, while the threads produced have ample strength for ordinary commercial work.

It is recognised that if advantage be taken of the generous tolerance allowed on the minor diameter of a nut, the crest of the thread will be flat, (as shown by the upper limit outlined for the nut in Fig. 8). This suggests the use of a modified form of Whitworth thread with flat crests with the object of providing ample clearance at the crest and roots of the mating threads.

The upper limit for the effective diameter of B.S.W. and B.S.F. nuts will be reduced by about 0.002 in. in consequence of the elimination of the 0.002 in. positive allowance on nuts.

The tolerances on the minor or core diameters of nuts have been increased above the present tolerances as the latter have been found

***Table VIII.—TAP DRILL SIZES (CORE DIAMETER)**

Nominal size In.	British Standard Whitworth: Nom'al root dia. In.	British Standard Whitworth: Tapping drill In.	British Standard Whitworth: Tapping drill Size	British Standard Fine: Nom'al root dia. In.	British Standard Fine: Tapping drill In.	British Standard Fine: Tapping drill Size
1/8	0.0929	0.0935	No. 42	—	—	—
3/16	0.1654	0.1653	4.2 mm.	0.1731	0.1732	4.4 mm.
1/4	0.1860	0.1875	3/16 in.	0.2007	0.2008	5.1 mm.
9/32	—	—	—	0.2320	0.2322	5.9 mm.
5/16	0.2414	0.2420	C	0.2543	0.2559	6.5 mm.
3/8	0.2950	0.2950	M	0.3110	0.3110	7.9 mm.
7/16	0.3460	0.3464	8.8 mm.	0.3664	0.3661	9.3 mm.
1/2	0.3933	0.3937	10 mm.	0.4200	0.4212	10.7 mm.
9/16	0.4558	0.4567	11.6 mm.	0.4825	0.4842	12.3 mm.
5/8	0.5086	0.5079	12.9 mm.	0.5335	0.5315	13.5 mm.
11/16	0.5711	0.5709	14.5 mm.	0.5960	0.5938	19/32 in.
3/4	0.6219	0.6250	5/8 in.	0.6433	0.6496	16.5 mm.
13/16	0.6844	0.6875	11/16 in.	0.7058	0.7087	18 mm.
7/8	0.7327	0.7344	47/64 in.	0.7586	0.7656	49/64 in.
1	0.8399	0.8438	27/32 in.	0.8719	0.8750	7/8 in.
1 1/8	0.9420	0.9449	24 mm.	0.9827	0.9843	25 mm.
1 1/4	1.0670	1.0780	1 5/64 in.	1.1077	1.1090	1 7/64 in.
1 3/8	1.1616	1.1610	29½ in.	1.2149	1.2190	1 7/32 in.
1 1/2	1.2866	1.2810	1 9/32 in.	1.3399	1.3390	34 mm.
1 3/4	1.4969	1.4960	38 mm.	1.5670	1.5630	1 9/16 in.
2	1.7154	1.7190	1 23/32 in.	1.8170	1.8130	1 13/16 in.
2 1/4	1.9298	1.9290	49 mm.	2.0366	2.0310	2 1/32 in.
2 1/2	2.1798	2.1880	2 3/16 in.	2.2866	2.2830	58 mm.
2 3/4	2.3841	2.4020	61 mm.	2.5366	2.5590	65 mm.
3	2.6341	2.6380	67 mm.	2.7439	2.7500	2¾ in.

***Table IX.—TAP DRILL SIZES FOR 75% THREAD DEPTH**

Nominal dia. of screw In.	British Standard Whitworth: Nom'al root dia. In.	British Standard Whitworth: Tapping drill In.	British Standard Whitworth: Tapping drill Drill size	British Standard Fine: Nom'al root dia. In.	British Standard Fine: Tapping drill In.	British Standard Fine: Tapping drill Drill size
1/8	0.0929	0.1015	No. 38	—	—	—
3/16	0.1654	0.1800	No. 15	0.1731	0.1850	No. 13
1/4	0.1860	0.2031	13/64 in.	0.2007	0.2130	No. 3
9/32	—	—	—	0.2320	0.2420	C
5/16	0.2414	0.2570	F	0.2543	0.2660	H
3/8	0.2950	0.3150	8 mm.	0.3110	0.3281	21/64 in.
7/16	0.3460	0.3680	U	0.3664	0.3860	W
1/2	0.3933	0.4219	27/64 in.	0.4200	0.4375	7/16 in.
9/16	0.4558	0.4844	31/64 in.	0.4825	0.5000	½ in.
5/8	0.5086	0.5313	17/32 in.	0.5335	0.5512	14 mm.
11/16	0.5711	0.6094	39/64 in.	0.5960	0.6250	5/8 in.
3/4	0.6219	0.6563	21/32 in.	0.6433	0.6693	17 mm.
13/16	0.6844	0.7188	23/32 in.	0.7058	0.7283	18.5 mm.
7/8	0.7327	0.7656	49/64 in.	0.7586	0.7874	20 mm.
1	0.8399	0.8750	7/8 in.	0.8719	0.9055	23 mm.
1 1/8	0.9420	0.9844	63/64 in.	0.9827	1.0236	26 mm.
1 1/4	1.0670	1.1094	1 7/64 in.	1.1077	1.1417	29 mm.
1 3/8	1.1616	1.2188	1 7/32 in.	1.2149	1.2599	32 mm.
1 1/2	1.2866	1.3437	1 11/32 in.	1.3399	1.3780	35 mm.
1 3/4	1.4939	1.5551	39.5 mm.	1.5670	1.6142	41 mm.
2	1.7154	1.7813	1 25/32 in.	1.8170	1.8701	47.5 mm.
2 1/4	1.9298	2.0079	51 mm.	2.0366	2.0938	2 3/32 in.
2 1/2	2.1798	2.2500	2¼ in.	2.2866	2.3229	59 mm.
2 3/4	2.3941	2.4800	63 mm.	2.5366	2.5635	2 9/16 in.
3	2.6341	2.7170	69 mm.	2.7439	2.8125	2 13/16 in.

*communicated by Thos. Firth & John Brown, Sheffield.

TABLE X.—ACCURACY OF B.S.W. TAPS OF CONTINENTAL MANUFACTURE

Size in.	Threads per in.	Cut tap		Ground tap		Precision-ground tap	
		PERMISSIBLE TOLERANCES					
		Per 1 in. length of pitch Inch	Of half the angle of thread Min.	Per 1 in. length of pitch Inch	Of half the angle of thread Min.	Per 1 in. length of pitch Inch	Of half the angle of thread Min.
$\frac{1}{4}$	20	± 0.002	±30	± 0.0004	±30	± 0.0002	±30
$\frac{5}{16}$	18	± 0.002	±30	± 0.0004	±30	± 0.0002	±30
$\frac{3}{8}$	16	± 0.002	±30	± 0.0004	±30	± 0.0002	±30
$\frac{7}{16}$	14	± 0.002	±30	± 0.0004	±30	± 0.0002	±30
$\frac{1}{2}$	12	± 0.002	±30	± 0.0004	±30	± 0.0002	±30
$\frac{5}{8}$	11	± 0.002	±25	± 0.0004	±25	± 0.0002	±25
$\frac{3}{4}$	10	± 0.002	±25	± 0.0004	±25	± 0.0002	±25
$\frac{7}{8}$	9	± 0.002	±25	± 0.0004	±25	± 0.0002	±25
1	8	± 0.002	±25	± 0.0004	±25	± 0.0002	±25
$1\frac{1}{8}$	7	± 0.002	±20	± 0.0004	±20	± 0.0002	±20
$1\frac{1}{4}$	7	± 0.002	±20	± 0.0004	±20	± 0.0002	±20
$1\frac{3}{8}$	6	± 0.002	±20	± 0.0004	±20	± 0.0002	±20
$1\frac{1}{2}$	6	± 0.002	±20	± 0.0004	±20	± 0.0002	±20
$1\frac{5}{8}$	5	± 0.002	±15	± 0.0004	±15	± 0.0002	±15
$1\frac{3}{4}$	5	± 0.002	±15	± 0.0004	±15	± 0.0002	±15
$1\frac{7}{8}$	$4\frac{1}{2}$	± 0.002	±15	± 0.0004	±15	± 0.0002	±15
2	$4\frac{1}{2}$	± 0.002	±15	± 0.0004	±15	± 0.0002	±15

to be too close for general production purposes. Refined tolerances permit of the use of tapping drills of ample size (75%) for facilitating tapping and minimising the risk of tap breakage, particularly with the smaller sizes of threads. Table X gives a comparison of accuracy for cut, ground and precision ground taps taken from the specification of a prominent Continental manufacturer.

An accurate tap must possess the following features :—

(1) The tap must be straight and concentric.

(2) The shape of the flutes must be correct and suitable for the material being cut.

(3) The following important dimensions must be accurate (*a*) effective diameter, (*b*) pitch, (*c*) angle of thread, (*d*) flank angle in relation to tap axis.

(4) Correct cutting angles.

(5) The material of the tap must be of high quality steel properly treated throughout manufacture up to the final grinding.

The high-speed steel used should have the following analysis :—

	W	Cr	Va	Co
Ordinary	18	4	1	—
Superior	18	4	1	5

Very thorough tests have been made[1] as described later, to find the most favourable working conditions for the ordinary machine tap[2] cutting mild steel of 30 tons per sq. in. tensile strength and cast iron. The results are indicated in Fig. 9 and the accompanying table.

The life of the tap is determined by the number of regrinds possible, before it is worn out. To obtain an idea of the length of life, it is necessary to consider not only the amount of relief, but the amount of interference of the new tap. If the relief is small, it is, as above mentioned, practically possible to grind away the total width of the tap land from the front edge to the back, without making the diameter smaller than the permissible dimension. It must not be forgotten, however, that the size that the tap actually cuts (amount of interference) must be greater than the allowance on the effective diameter, this being so for all kinds of taps and with every shape of thread except the unusual square thread.

A tap should only be worn out when the lands have been ground in sharpening, until the remaining portion will only just withstand

[1]*Werkstattstecknik*, 1925, pages 601 to 616.
[2]*Werkstattstecknik*, 1926, page 644 ; and *Machinery*, 1928.

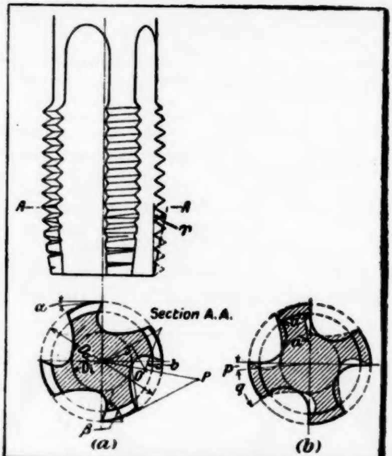


Fig. 9. *a*—Correct form of tap as indicated by tests. *b*—Obsolete cross-sectional form.

Angle of chamfer $\gamma = 10°$. Di = ½ Da.; 4 flutes. Straight cutting faces *b*.
Forms of flutes composed of two arcs with centres *O* and *P*, as seen in the figure.
Relief *q* only on the chamfer and up to the cutting edge.

Radial relief angle of chamfer $\alpha \simeq 5°$.

Number of threads with full profile equal to number of threads in the nut allowing for regrinding.

Depth of blind hole equal to length of full thread plus $\frac{\text{Da.}}{2}$

Three taps of one set for the blind hole replaced by one single tap for the through hole.

Comparison of commercial (———) section of tap with improved shape (- - - -), according to tests (*b*).

Weakest part of the flank $a = a^1$.

p = circular arc, not backed off.

Cutting angle β = 68 to 75°. Rake angle $90° - \beta$ = 22 to 15°.

(This indicates that taps generally have insufficient rake. Gun-nosed taps are now being made with rake angles as above.)

the load imposed without breaking. At this stage the tap should still cut within the tolerance for size.

As the crests of rounded thread forms (Whitworth and B.A.) wear more rapidly than the flanks, it is necessary to provide for additional life of the crest by means of an increased positive tolerance.

In addition, as the tap lands have radial relief, it is necessary to keep the sum of the increased diameters due to radial relief, manu-

facturing tolerances, and to crest wear allowance, within the tolerance of the thread size allowed for the tap.

With flat-topped threads the crest allowance is not necessarily greater than the manufacturing tolerances.

Core Diameter of Taps.

To ensure a good fit between the flanks of the bolt and the nut, not only must the major (external) diameter of the tap be larger than the nominal dimension, but the same applies to the minor (core) diameter. If the Whitworth thread has a crest which is larger than the nominal radius, this can only be at the expense of errors in flank angles. If the minor diameter be smaller, which is not unusual, and if the bore of the nut is not drilled large enough, a

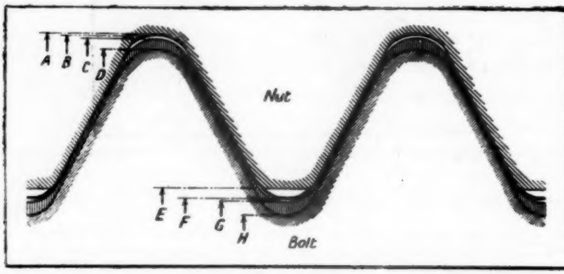


Fig. 8. Diagram of mating Whitworth threads showing the effects of tolerances.

bolt of exact nominal diameter could not be introduced, even though the tap was large enough on all other dimensions ; but this is a very rare case. Generally, the minor diameter of a tap is of secondary importance, because the bore of the nut is always made larger than the theoretical core diameter. The crests of the threads in the bore of the nut are then flat and not rounded. Fig. 8 shows the clearance between the crest of the bolt and the major diameters of the nut of the British Whitworth standard.

The heavy curve *A B* signifies the permissible tolerance of good ground hand taps. The vertically cross-hatched surface represents the tolerance of bolts according to the British Standards Institution, which fixes also the maximum and minimum diameter of the bore of the nut. To decrease the friction between tap and nut as much as possible it is recommended that all taps be made with the above-mentioned back taper, so that the diameter of the threaded part of the tap is diminished from the cutting point to the shank. This reduction for hand taps of $\frac{1}{4}$ in. diameter is 0.00025 in. and for a tap of 1 in. diameter, 0.002 in. These allowances are

varied to suit the different diameters. Besides reducing friction, this back taper assists in preventing clogging of the material on the taps and so helps to avoid breakage.

A = the maximum dimension of the major diameter of the tap.
B = the minimum dimension of the major diameter of the tap.
C = the maximum major diameter of the bolt.
D = the minimum major diameter of the bolt.
E = the maximum minor diameter of the nut.
F = the minimum minor diameter of the nut.
G = the maximum minor diameter of the bolt.
H = the minimum minor diameter of the bolt.

Taps, both ground and unground, should be made as shown in Fig. 11, but the length of the chamfer should be kept to a minimum. The threads should be taper cut (Fig. 10 correct) not merely taper

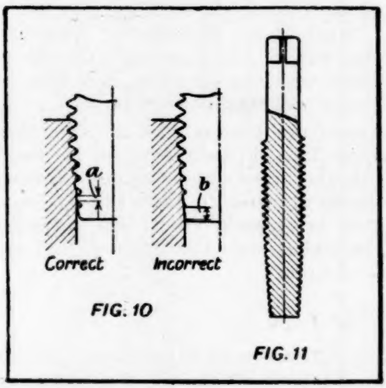


Fig. 10. Correct form of taper tap.
Fig. 11. Correct and incorrect forms of chamfer.

turned on the external diameter (Fig. 10 incorrect). This is the best means of avoiding the destruction of the first threads of the nut by reaming instead of obtaining a correct thread-cutting action. The width of the cut is reduced with the correct shape *a*, as compared with the wrong shape *b*.. The wide face *b* has generally the effect of shearing off the crests of the first threads, giving a reaming action.

Some reasons for the unsatisfactory cutting of a tap are :

(1) On the WORKPIECE : tapping hole drilled too small. Hole not aligned with the tap.

(2) On the TAP : chamfer too long or too short, or not uniform at all edges. Teeth incorrectly ground and/or incorrectly sharpened. Relief in wrong direction. Tap not fed-in properly.

Tap not running true. Tap twisting in hole. Wrong speed, unsuitable coolant.

(3) On the Machine: Surface of table not at right angles to axis. Inaccurate chucking of tap. Main spindle loose in its bearings. Tap eccentric to the bore. Taps cannot align themselves without producing bell-mouthed holes. Axial (+ or —) pressure on the tap.

Hand Taps.

Fig. 12, *a—c*, illustrate the cutting action of an ordinary set of three hand Whitworth taps, as applied to a blind hole. The taper tap has a chamfer angle of $\alpha = 3°$, corresponding to a length of $12\frac{1}{2}$ threads, the second tap an angle, $\beta = 7\frac{1}{4}°$, corresponding to five threads, and the bottom tap an angle $\gamma = 23\frac{1}{4}°$, corresponding to $1\frac{1}{2}$ threads. Angles vary slightly for different thread forms. Fig. 12a shows the thread after tapping with the taper tap, Fig. 12*b*, after threading with the plug tap, and Fig. 20*c* the finished thread after tapping with the bottom tap.

If a set of taps of this kind is used to tap a through hole, the second and bottom taps do no real work because the thread is almost finished by the taper tap. They do, however, smooth the surfaces of the flanks and size the thread to the required tolerance, provided that they are from 0.004 to 0.01 in. larger in diameter. Any sizing tap should remove this amount, and should have the shortest possible chamfer.

Special Forms of Taps

Fig. 13 shows a different method for tapping a blind hole (*b-c-d*) using a set of hand taps in which only the bottom tap has the full major diameter on its cutting part similar to set shown in Fig. 5. Here the taper tap has an angle of chamfer of $\alpha = 5\frac{1}{2}°$ (operation *b*), or representing a length of four threads; the second tap has an angle $\beta = 13\frac{3}{4}°$ or $2\frac{1}{2}$ threads (operation *c*), and the bottom tap an angle $\gamma = 23\frac{1}{4}°$ or $1\frac{1}{2}$ threads (operation *d*).

These serial taps must have reduced effective diameters at the nose to allow them to enter the holes made by previous taps, especially in the case of large taps, from $1\frac{1}{2}$ in. upwards. These taps are very effective, both as regards cutting and finish.

Fig. 13 *e-h* show the distribution of work in tapping a through hole with a similar series of hand taps with different outside diameters. The same taps are used as those employed for a blind hole. The state of the hole after tapping with the first, second and third taps is illustrated in Fig. 13 at *e*, *f*, and *g*, respectively. From this comparison it is evident how much less work the second and third taps

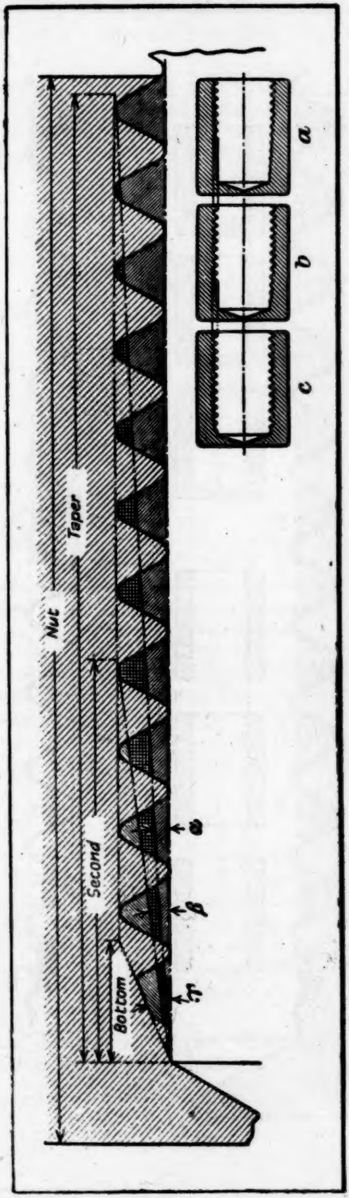


Fig. 12. Diagrams illustrating the cutting action of a set of three hand taps.

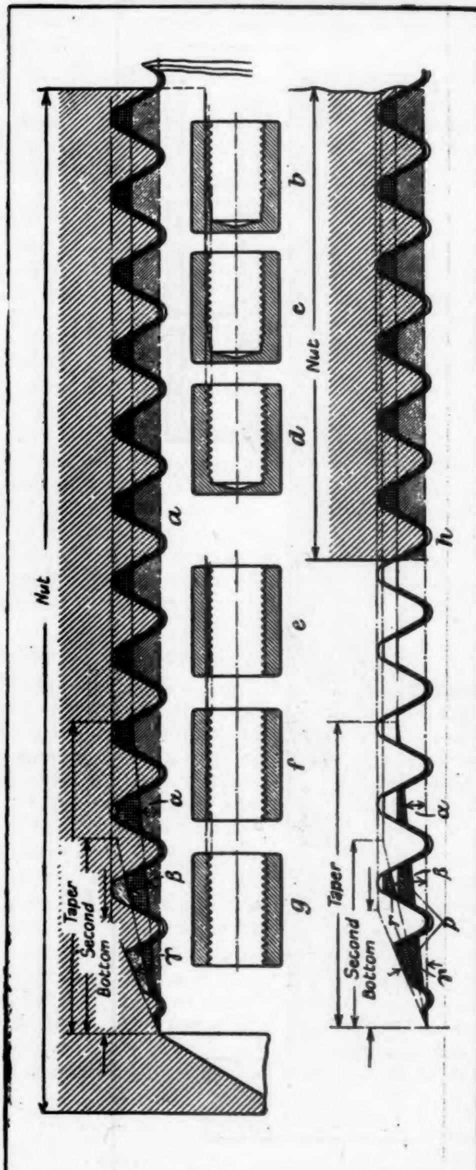


Fig. 13. Diagrams illustrating stages in the tapping of blind and through holes with taps of varying outside diameters.

have to do in cutting a through-hole (Fig. 13*g*), than in cutting a blind hole. (Fig. 13*d*).

Improved cutting performance may often be obtained by varying the grinding of the flanks, flutes or chamfer, and examples of such modifications are shown in Fig. 14 to 16. The tap in Fig. 14 is used for through holes and that shown in Fig. 15 for blind holes. Taps as shown in Fig. 14 are an improvement on the type illustrated in

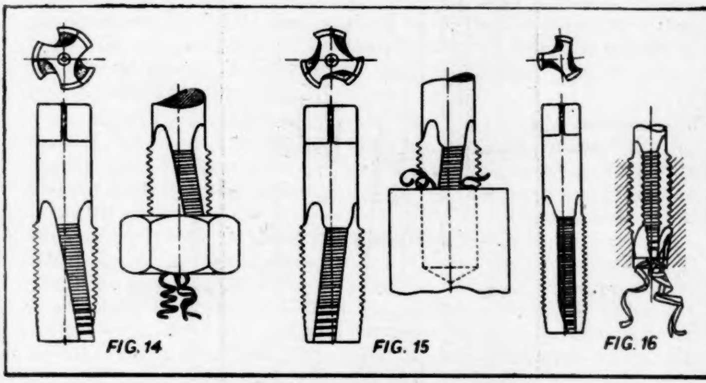


Fig. 14. Right-hand tap with left-hand spiral flutes.*
Fig. 15. Right-hand tap with right-hand spiral flutes. Fig. 16. Gun-nose tap.

Fig. 4, and are used for through holes in tough steels. They do not cut such a clean thread as ground taps with correct spiral flutes, but have the advantage of removing the chips in front of the tap, and thereby reducing the danger of tap breakage due to clogging with chips. These taps are very efficient both as regards cutting and finish.

Gun-nose Taps.

The gun-nose tap (Fig. 16) is gradually ousting other forms, where through holes are required. Owing to the form at the nose and to the very keen front rake, combined with a carefully designed chamfer, a series of thin, continuous chips is produced, which are directed ahead of the tap, so that the chip clearance problem is solved. This is the most efficient tap yet made. The front rake ranges up to 25/30°, and the clearance on the chamfer is 0.002—0.003 in. per land.

Such taps are difficult to regrind and require the services of a skilled man, unless fixtures are available.

* comp. Werkstadtstechnik 1926 to 1928 and Machinery, New York 1928.

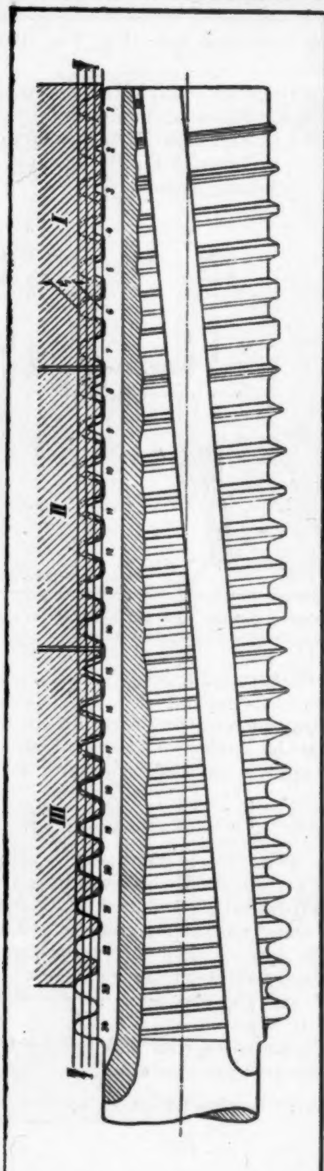


Fig. 17. A tap which divides the thread cutting operation into three stages.

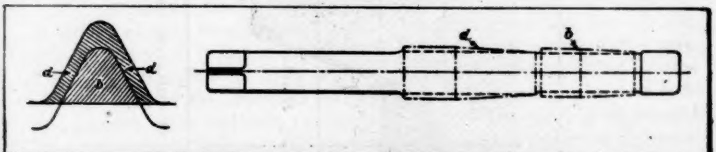
The tap shown in Fig. 15, having flutes with a right-handed spiral, tends to remove the chips in a backward direction towards the shank in a similar manner to a twist drill. For this reason it is useful for tapping blind holes, since it helps to avoid compressing the chips at the bottom of the hole.

The difficulties of producing interchangeable threads economically with taps has led some firms to divide the threading action into stages. The cutting action is thus distributed between several processes on the same tap, various methods being in use. One type—the eccentric tap—first removes material from the middle of the thread groove, leaving stock on both flanks. This is subsequently cut away by other teeth.

In Fig. 17 the depth of the thread t_1 is divided between the operational stages I to III, and there is a group of cutting teeth for each stage. The first three teeth (1, 2, 3) have increasing diameters and cut a small gap up to line *I—I* (Fig. 18). The teeth 4 to 7 increase in width and widen the groove by cutting the flanks almost up to the required profile. During this operation teeth 8 to 10 of group II, which again increase in diameter, begin to cut up to the line II—II. The next group again widens the groove and finally the procedure is repeated by group III until the thread is finished. The last teeth give a very fine finish and ensure an accurate profile. By this distribution of machining the work is facilitated and, above all, chips are prevented from clogging the teeth, tap breakage being reduced. When using this type of tap it is not necessary to have plug and bottom taps, the work being done with one single tool, thus saving time and expense.

The Tandem Tap.

Fig. 19 illustrates the so-called tandem tap, which is particularly useful for cutting long through threads on a machine. This tap consists of two threaded portions, one behind the other, which are separated from each other by a small recess. The front portion *b*



X

Fig. 19. A tandem tap for cutting long threads in through holes.

has a pilot, the diameter of which is equal to the core diameter of the thread. Both portions are generally alike, except that the front portion behind the pilot has a somewhat smaller diameter, so that

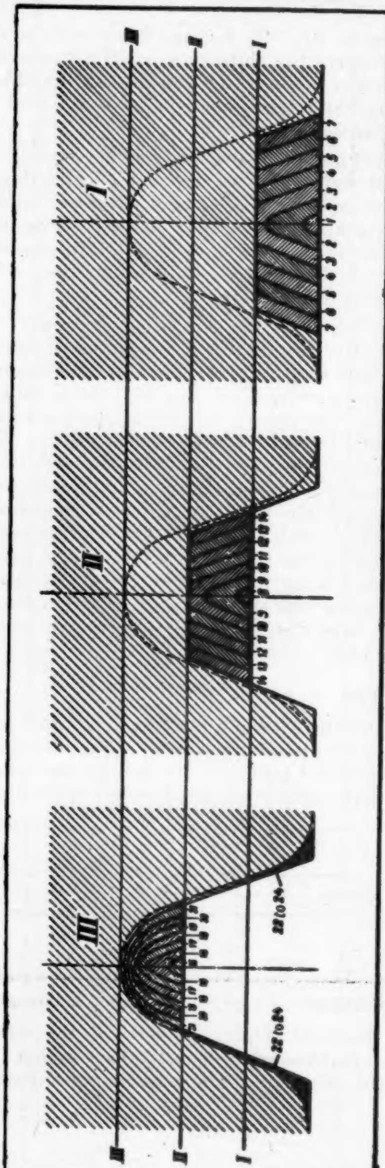


Fig. 18. Diagrams showing how the cutting action is distributed over the teeth of the tap in Fig. 17.

the finishing of the thread to the required tolerances is performed by the second portion *d*. This type of tap produces threaded holes of accurate form and diameter, and with very smooth flanks to the threads. Much time is saved because two taps are, in effect, provided on one shank. With this design it is unnecessary to use a series of taps, since a finished tapped hole is produced by the single tool. The tandem tap is better guided in the bored hole than an ordinary tap. At X in Fig. 19 is shown a magnified section of the thread and the distribution of work between the portions *b* and *d*.

Cutting Trapezoidal (Acme) Threads with Spiral Ground Taps.

Formerly it was very difficult to cut an Acme nut accurately, partly because of the steep angle of the flanks and partly because of the large pitch and depth of thread in relation to the diameter. Consequently such threads were cut either completely on the lathe with a single-point tool, or roughened on a lathe and then finished with a master tap. Both processes are expensive and do not give the best results as regards accuracy. Using spiral fluted ground Acme taps that have been correctly relieved, trapezoidal nuts can be cut in any material, within the permissible tolerances. It is evident that spiral flutes are not absolutely necessary in this case, because the pitch is steep and the depth great in relation to the diameter; the success of taps of this type is not only due to the use of spiral grooves, but must also be attributed to other special features of design. The work must be distributed between one or more roughing taps and one finishing tap. The number of roughing taps must be chosen according to the length of the nut to be tapped, also its diameter and pitch. The last roughing tap almost finishes the external diameter of the thread, but it leaves the grooves in the nut somewhat narrower than those of the finished thread; then, with the finishing tap, the inclined flanks are finished and the external diameter smoothed.

Design of Acme Taps.

Fig. 20 shows a set of Acme taps and indicates the distribution of work between the different taps. The first taper tap has a pilot, the diameter of which is equal to the internal diameter of the nut. This pilot is followed by a short chamfered portion which serves to take hold of the material suddenly and advances the tap to give the correct pitch without reaming the hole. The pilot is separated into two cutting edges at the crest of the thread in order to decrease the width of the cut, so that the tap has better guidance in the bore.

Each tap has two chamfered sections which are separated from each other by a cylindrical non-cutting part. This is because Acme nuts are generally long and the work done by the tap would be

excessive if the tool were cutting at the same time over the whole length. The lengths of the corresponding threaded sections are therefore made so that the length of the first chamfer plus the length

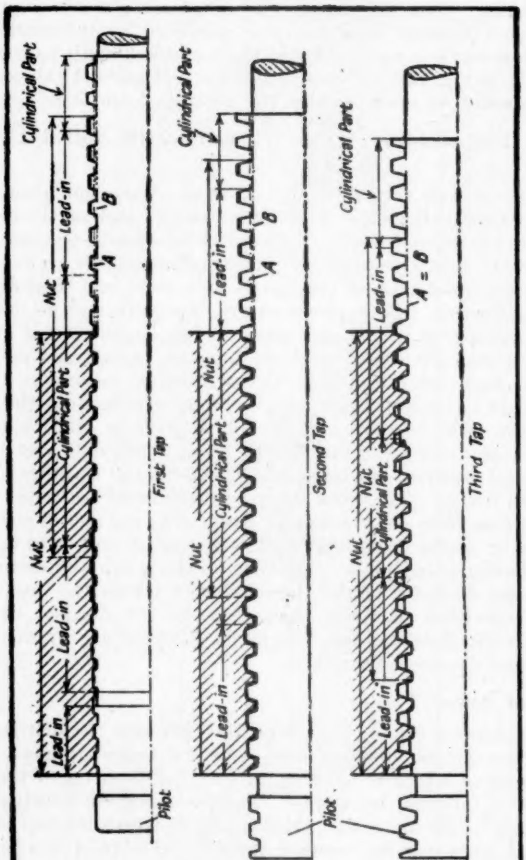


Fig. 20. A set of three taps for Acme threads

of the following cylindrical threaded part are approximately equal to the length of the nut. When the first chamfered portion begins to leave the bore, the next section continues the cut. The length of

each chamfered portion is never more than double the external diameter and in no case longer than 2 in. In Fig. 20 A is the core diameter of the nut, and B is the core diameter of the tap. The core diameters of nut and tap are equal for the third tap of the set, so that $A = B$.

As an example, suppose that an Acme thread is to be cut in a nut 3 in. long, and that the thread is 1 in. in diameter and six t.p.i. The first chamfered portion would be $1\frac{1}{4}$ in. long, and the adjacent cylindrical part $3 - 1\frac{1}{4} = 1\frac{3}{4}$ in. The second chamfer would also be $1\frac{1}{4}$ in. long and the adjoining cylindrical part would have a length of 1 in. With this design there is never more than $1\frac{1}{4}$ in. length of chamfer cutting at one time. The pilot of the second tap is somewhat smaller in diameter than the last cylindrical part of the first tap. The same applies to the pilot of the third tap.

Acme taps of this design, finish ground and with spiral flutes, can be used for cutting all kinds of material if care is taken that the angle of rake of the cutting edges is adapted to the material to be machined. The number of taps in a set depends primarily on the length of the nut, the pitch of the thread and on the material. In cutting cast iron with a strong tap, each tooth can easily take a cut 0.004 in. in depth. If the taps are smaller, or if they have a coarse pitch of weak threads, each tooth must cut correspondingly less. In bronze, which is generally tough, the tooth should not take a deeper cut than in ordinary steel, namely about 0.003 in. For a tap with two chamfers in tandem, or a set of two taps each with one chamfer, the work is best distributed so that the first tap takes two-thirds of the total cut and the finishing tool one-third.

Relief of Acme Taps

The backing-off of Acme taps depends on the diameter of the tap and the material to be machined. A tap of $1\frac{1}{4}$ in. diameter generally has a relief of approximately 0.006 in. at the effective diameter, 0.003 in. at the external diameter, and 0.01 in at the external diameter of the chamfer. If the material is tough and tends to clog easily on the flanks of the teeth, the relief must be greater. Of great importance is the space for swarf removal. The longer the nut and the greater the cut of each tooth, the more the space or chip chamber which must be provided for swarf removal. If ample swarf space can only be provided by reducing the strength of the tap, it is advisable to use two taps, or more if necessary.

Design of Stay-bolt Taps.

Fig. 21 shows, among a number of special taps, a long stay-bolt tap ground on the thread. The advantages of grinding the thread are particularly marked with this type of tool. Such taps are made

with either spiral or straight flutes because the pitch is small in relation to the diameter. The number of flutes is usually uneven (three or five), because these taps work satisfactorily in wrought-iron boiler sheet or copper, only if the thread is cut away alternately on one tooth following the other. An uneven cut is thus only possible if the number of flutes is uneven. If a tooth follows a space on each successive row, the chips are broken up more easily, swarf disposal is facilitated, and the coolant is more effective. Stay bolt taps are

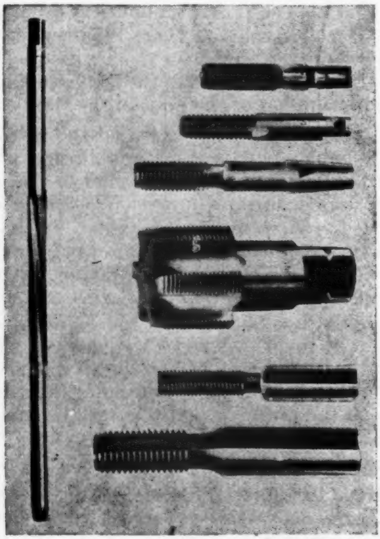


Fig. 21. Special taps with various forms of shanks, including a long stay-bolt tap.

made with ground threads in lengths up to 7 ft. and 1½ in. in diameter. These tools have a guaranteed accuracy of pitch of 0.00004 in. over ½ in. length, therefore the pitch error does not exceed 0.01 in. between the two ends of the tap.

Long taps, heavily loaded, twist between the drive and the points of resistance, and in this way errors may be introduced.

Number of Flutes.

The number of flutes is not standardised, it being usual to find one, two, three, four, five, six or eight flutes. Single-flute taps are

sometimes used for aluminium. A two-fluted tap, as shown in section on the left in Fig. 22, is only used for soft material and short holes, the cutting action being similar to that of a twist drill. Two

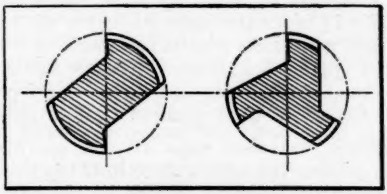


Fig. 22. Sectional views of a two-plate (left) and three-flute taps.

cutting edges are sufficient for soft material and will stand up during the tapping of thousands of work pieces. The two flutes provide maximum chip space. Three-fluted taps, as seen on the right in Fig. 22, are said to cut more easily and with fewer shocks than those

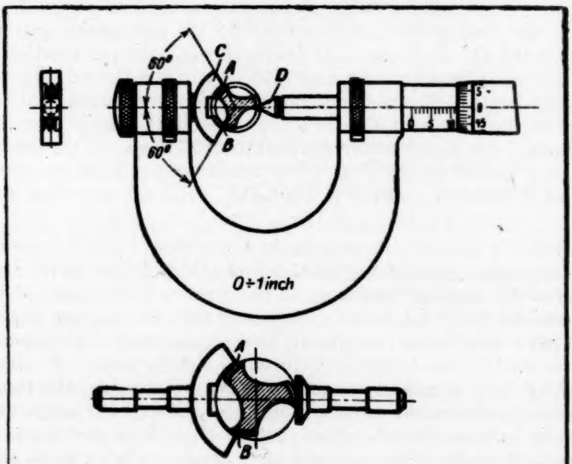


Fig. 23. Reishauer micrometer for measuring three-flute taps. The main view shows the anvils for checking effective or core diameters, and the lower view the anvils for the external diameters.

with four flutes, because three flutes gives a good balance between number of cutting edges and chip clearance. The four-fluted tap, however, has better guidance on the chamfer. Moreover, and this

is an important point, it can be measured more easily using ordinary micrometers or gauges. Correctly ground three-flute taps have fewer edges, and consequently friction is reduced. If the chamfers of three- and four-flute taps are the same, one tooth of the three-flute tap removes $1\frac{1}{3}$ times the material that is cut by a tooth of the four-flute tap and more flute area is necessary to accommodate the larger chip. The cutting lips, however, can be made stronger, while at the same time maintaining sufficient chip space, regrinding occupies only 75% of the time required for four-flute taps.

As stated above, four-flute taps may be checked with simple measuring instruments, but with a three-flute tap this is not possible. The flank micrometer, however, shown in Fig. 23, enables three-flute taps to be measured by means similar to those employed for the four-flute type, and the method can be adapted to existing calipers, micrometers, microstats, etc. In the main view, Fig. 23, *D* is tapered to a point which has an angle corresponding to that of the thread to be measured (60°, 55°, etc.). The notch-anvil *C* is made as a sector of a hardened ring with a ground internal thread (B.S.W., B.S.F., B.A., etc.). It has two measuring edges, *A* and *B*, which are arranged at angles of 60° to the measuring axis of the bevel point *D*. The axis of *D* passes through the intersection point of the thread flanks at the root diameter of the thread. The exact readings for the effective and core diameters are determined beforehand on the micrometer scale using a standard piece. The taps to be checked are then compared with these readings. As the tolerances are very small the inherent error within the instrument does not exceed 0.00004 in., which is negligible even for precision ground taps.

The major diameter, as seen in the lower view, Fig. 23, is measured with a simple sector of a ground cylindrical bore, the bevel *D* being replaced by a plane surface. It is of great importance that the flute should be of the correct shape and that the cutting angle and front rake should also be correct. The circular part of the tap, which acts as a pilot, was formerly reduced to size by filing. To-day it is produced by a grinding operation, either by grinding the flanks or by relieving the whole tooth profile. The relieved shape, if it is not correctly ground, has the disadvantage that chips may be trapped between the bore of the nut and the cutting surfaces when the tap is backed out, this reversal being necessary for all blind holes and also for a good many threads which are produced on capstan and combination turret lathes.

In Fig. 24 the back angle a of the flute is made about 80°. This is sufficient to prevent pinching of the chips when backing out the tap. Against the shape shown in Fig. 24 the objection is often raised that in reversing the tap both the cutting edges and the

finished flanks are damaged. There are no grounds for this objection. The real cutting action is performed only by the chamfer of the tap, which is relieved on the top either by filing, turning or grinding, whilst the cylindrical part of the tap is used only for guidance and size regulation. The chamfer is the same for all shapes of flutes, and when the tap has made flute revolutions of reversal, the chamfered portion is free, and consequently cannot cut if the shank of the tap is correctly guided.

Faulty threads may be considered with regard to parallelism, maintenance of form throughout the length, pitch, thin threads,

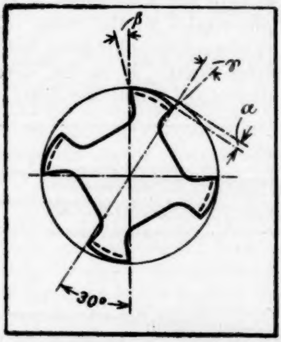


Fig. 24. Sectional view of tap, showing front and back rake angles and relief.

bell mouth, truth with the axis of the hole, torn threads and bad finish.

It should be noted that in a set of three standard taps the bottom tap and second tap are both of the same size, so that the bottom tap cannot be used as a sizing tap after the second tap, although it can be used for bottoming. It will also, of course, size a through hole after the taper tap.

It should be borne in mind that one revolution of the tap in the job advances the tap by one pitch and produces one thread of correct depth, providing the whole length of chamfer is engaged in the work. Thus the work of producing one thread is a constant for any one tap and the effect of varying lengths of chamfers is to distribute the load over as many edges as desired. Numerous edges are used, if there is plenty of room, as in through holes, ensuring thin chips and long life. There are fewer cutting edges in the case of blind holes, where the run-out is short. This results in heavy loading per edge and short life, but the total load is the same. For all standard screw sizes the torque that a tap can transmit is suf-

ficient to drive the tap with the chamfer fully engaged, providing, of course, the tap is properly designed and sharpened.

Modern taps are ground after hardening to eliminate distortion and other irregularities. They must be ground with a correctly shaped grinding wheel on a grinding machine with an accurate lead screw. The manufacturer who wishes to produce interchangeable bolts and nuts within the prescribed tolerances (see B.S.I., Tables II and VI), must use ground taps, and use them correctly.

Advantages and Disadvantages of Spiral Flutes.

The spiral flutes of taps are sometimes (S.K.F. taps*) so milled that they are at right-angles to the helix of the threads, as in fig. 25 ; only if this relationship holds good will both flanks of the thread cut at the same time. It is not necessary for standard threads, but is an advantage when the helix angle is large as in

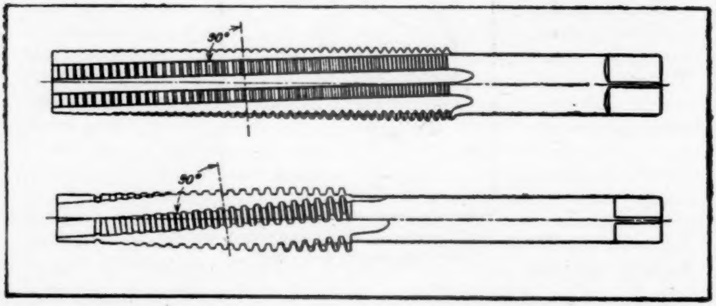


Fig. 25. Taps with spiral flutes at right angles to the thread helix.

Acme and multi-start threads. The power required for tapping is reduced and the thread is cut cleanly and accurately. Both flanks of the cut thread have the same accurate profile which is not the case with threads that are cut with straight fluted taps, even though the taps are ground.

Taps with spiral flutes control the chip flow (Figs. 14 to 16), the swarf being directed ahead of the tap. Owing to this action clogging of the chips in the flutes is to a large extent prevented and risk of tap breakage is reduced. If the angle of the spiral is small, as when cutting a fine pitch thread of large diameter, spiral flutes are of no great practical value. To prevent the chips being pushed in front of the tap for blind holes with right-hand threads, left-hand spiral taps cutting right hand should be used. Generally speaking, in

* Tests made by S.K.F. Gothenburg, Sweden, 1928. (see S.K.F. Ground Taps Booklet of Alfred Herbert, Ltd., Coventry.)

tapping blind holes, particularly on vertical machines, difficulties arise in connection with swarf removal when using both spiral fluted and straight fluted taps. The best shape of flute for this work is as mentioned, a steep spiral of opposite hand, as with a twist drill (see Fig. 15).

Shape of Two Flutes.

Usually all taps, whether ground or cut, have an even number of flutes to facilitate manufacturing, measuring and inspection. The only kind of taps which give better service with an uneven number of flutes are nut and stay bolt taps. Of great importance in the design of the taps is the shape of the flutes, and the following rules must be observed :—

(1) The flute shape must give appropriate front rake in order that the chips shall be cut correctly. It must be large enough to accommodate the chips and must also give the correct back rake (*a*, Fig. 24) to prevent jamming on reversal.

(2) The shape depends on the material on which the tap is to be used. The ordinary tap has a radial face, as in Fig. 24. For brass and similar materials a negative rake is preferred ; for general use on steel and bronze a straight face and a positive rake is to be recommended. Armour plate of 75 tons per square inch tensile strength has been cut with 10° (positive).

(3) The form of the flute must be such that in reversing the tap the chips are not pressed against the back of the teeth and then pinched between the threads in the hole and the backed-off teeth. If this should occur, the thread in the hole would probably be spoiled and the tap or at least some of its teeth broken. Minimum relief on threads and chamfer also positive rake at the head of the tap will help to prevent the swarf from entering the threads.

(4) The shape of the flute must be such that the teeth remain strong enough to resist fracture. At the same time the flute must be deep enough to allow space for the chips. Ample flute space is always to be recommended.

Figs. 26 to 29 and table XI give some data regarding the shape of the cutting edges and of the flutes. The old-fashioned commercial taps (Figs. 26 and 27) are fluted with a convex cutter *a*. The radius *R* and depth of the flute are equal to a quarter of the tap diameter for a tool with four flutes. The width of the land, is, for a four-fluted tap, somewhat greater than half the width of the flute.

The full draw line on the back of the land shows a modified improved shape of flute whereby the back of the land is made radial for a distance equal to $1\frac{1}{4}$ times the depth of thread. For these tools the angle of rake of the curved cutting edge is positive for 84% of the depth, and negative for the remainder of the depth near the root of the thread, which is incorrect. Fig. 26 shows a comparison

between flutes which are cut (1) with a convex cutter *a* ; (2) with a cutter of modified shape *b*. Another shape is shown in Fig. 27. The flute here is so deep that the cutting edge has a positive but

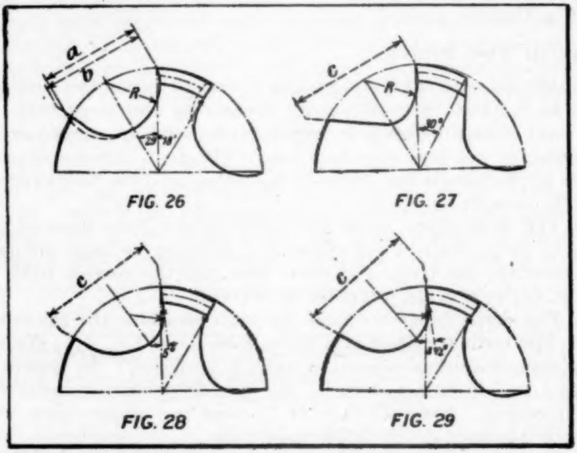


Fig. 26 (left). Obsolete shape of flute produced by (*a*) convex cutter, and (*b*) modified shape of cutter. The cutter (*a*) gives a rake angle at the outside diameter of $+ 14\frac{1}{2}°$ at the effective diameter of $+ 5\frac{1}{2}°$ and at the root diameter of $- 3°$.

Fig. 27 (right). Improved form of flute for machine taps produced by special still incorrect cutter (*c*). Angles of rake vary: α ext $= + 16\frac{3}{4}°$; β eff $+ = 8\frac{1}{2}°$; α root $= 0°$

Fig. 28 and 29. Correct flutes shapes produced by special cutters (*c*), giving constant front rakes of 5 and $8\frac{1}{2}°$. $d = 1\frac{1}{2}\,t$.

variable angle of rake over the full depth of thread from $+ 16\frac{3}{4}$ to $0°$. The angle of rake should be constant, as shown in Figs. 28 and 29.

The constant rake angle should extend from the chamfer through the first full finishing tooth. It depends only on the material to be cut. If the taps have straight flutes the rake angle is maintained

TABLE XI.—ANGLES OF RAKE FOR VARIOUS MATERIALS OF DIFFERENT HARDNESS AND RESISTANCE TO CUTTING

Material	Constant angle, α deg.
Cast iron (from 120 to 200 Brinell)	5 to 10
Steel from 20 to 50 tons per sq. in.	5 to 10
Hard cast iron...	} 0 to 5
Tough and resistant steel	
Light metals	20 to 25
Brass and bronze	0 to 5
Plastics (bakelite, resins)	0
Novotext	} 18 to 20
Vulcan fibre	

for the full length of the flute. If the chamfer rake is ground at a helix angle, as in a gun-nose tap, the rake angle varies.

Relief of Ground Taps.

The relief of the thread flanks can generally be less for taps with spiral flutes than for taps with straight flutes without increasing the power required for cutting. Both spiral-fluted ground threads and straight-fluted threads can now be relieved correctly, and both types of taps then cut with equal facility. The cutting teeth of the spiral-fluted tap support the tool over a greater part of its circumference and thus afford better guidance. The backed-off straight-fluted tap is only guided by as many straight lines or edges as the tap has flutes. The amount of relief on taps depends essentially on

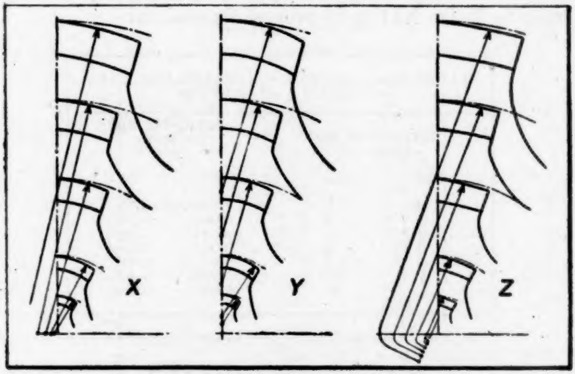


Fig. 30. Diagrams showing different forms of relief on taps.

the type of tap and the material to be cut. The rate relief of ground taps for general use should be constant behind each cutting edge. Because the width of the lands of taps of larger diameter is greater for a corresponding number of flutes (see Fig. 30, *X*), the total amount of the relief, *i.e.*, the difference in diameters measured over the cutting edges and the ends of the teeth is correspondingly increased.

Machine taps have more relief than hand taps, this generally being 1½ times as much. The tendency, however, is to reduce the relief of the chamfer of the taper tap in a set of three hand taps. As the lands of taps are relieved, only very little of the front faces of the tap teeth should be removed when re-grinding in order to ensure as long a life as possible.

The correct form of relief is essential, and Fig. 30 shows at *X*, *Y* and *Z* three different types. Fig. 30, *Y*, in which the centres of

the radii are on the vertical axis, is most commonly used for cylindrical and taper taps, but it is not considered so good as that shown in Fig. 30, *X*, in which the centres of the radii are on the horizontal axis.

The best form of relief is that in Fig. 30, *Z*, where the centres of the radii are on an inclined line. The tap made with this latter form of relief cuts well and has no tendency to produce oval holes. The chips do not clog on the oblique flanks of the thread in the same way as they tend to when the relief is as shown in Fig. 30, *X* and *Y*. In Fig. 30, *X*, the radius of the relief is equal to the radius of the tap. In Fig. 30, *Y*, the radius is smaller, and in Fig. 30, *Z*, larger than the radius of the tap, therefore the relief at the back of the tooth is less in Fig. 30, Z, than in Fig. 30, *X* and *Y*.

Taps for threading mild steels up to 50 tons per sq. in. with relief according to Table XII have proved satisfactory.

TABLE XII.—AMOUNT OF RELIEF FOR TAPS OF VARIOUS DIAMETERS.

Diameter of tap (inch)		Relief (*a*, Fig. 24)*, per tooth (inch)	
From	To	From	To
0.040	$\frac{1}{4}$	Without relief.	
$\frac{17}{64}$	$\frac{9}{16}$	0.002	0.0025
$\frac{19}{32}$	$\frac{7}{8}$	0.003	0.0035
$\frac{29}{32}$	$\frac{3}{16}$	0.004	0.0045
$1\frac{7}{32}$	$1\frac{5}{16}$	0.005	0.006
$1\frac{11}{32}$	2	0.0065	0.008
$2\frac{1}{32}$	3	0.0085	0.0095

* For cast iron, bronze and brass, these values are increased by 50%.

The Importance of Accurate Centring of Taps.

As ground taps are turned about their axes during all manufacturing operations, especially in grinding and backing-off, the careful centring of the blanks is of particular importance. The dimensions of the centre should not be decided with reference to the diameter of the blank, but rather in relation to the root diameter of the finished tap, otherwise the centres are easily made too large and too deep, thereby weakening the tool and causing tension during the hardening process, which frequently results in cracks. The centres (Fig. 31) must not, however, be too small, otherwise they will not give sufficient bearing to support the tap during the various manufacturing operations. The small cylindrical hole must be sufficiently deep to prevent the sharp point of the centre from touching the bottom of the bore ; but if this cylindrical hole is too long, cracks may occur as stated above.

Recommended dimensions for the centres of taps are contained

in the table below Fig. 31. These sizes have proved satisfactory in practice. Because it is difficult and expensive to make sufficiently small centres in taps of small dimensions, and because these centres would be, in any case, too small to provide the necessary support during machining, taps from ⅛ to ⅜ in. are frequently made with a 75° point at the end of the thread, and taps below ⅛ in. have these

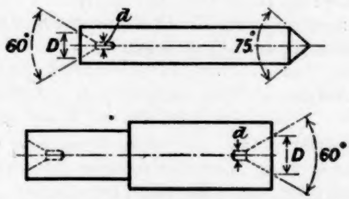


Fig. 31. Centre hole dimensions for taps of various sizes.

Size of taps *In.*	D *In.*	d *In.*
¼	0.1	0.06
5/16	0.1	0.06
⅜	0.12	0.06
½	0.13	0.08
⅝	0.16	0.08
¾	0.17	0.08
⅞	0.19	0.08
1	0.20	0.08
1⅛	0.20	0.08
1¼	0.21	0.10
1⅜	0.21	0.10
1½	0.22	0.10
1⅝	0.23	0.10
1¾	0.26	0.10
1⅞	0.28	0.10
2	0.29	0.12
2¼	0.29	0.12
2½	0.29	0.12
2¾	0.35	0.16
3	0.35	0.16

Correct centres of taps.

75° points at both ends. It is of great importance that the taper part of the centre is accurately circular. If this is not the case, the tap will be irregular and the relief of the thread flanks inaccurate. As the bright stock used for making taps has generally the minimum of material for removal, it is important that the blanks are centred accurately in order that the decarbonized surface around the external diameter of the rough piece may be removed.

Materials to be Machined.

The selection of an appropriate cutting speed, cutting angles and relief of the chamfer depend on the material. For taps to cut semi-hard, hard and tough steels up to 50 tons per sq. in. the relief of the chamfer should be as recommended in table XII.

Materials may be divided into the following groups :—

(1) Machinery steel up to 50 tons per sq. in.
(2) Tough and hard materials: Chrome steels, Cr-Ni and nickel steels, stainless steels and tool steels.
(3) Cast iron.
(4) Brass and bronze.
(5) Light metals.
(6) Plastics and resins.

Group (1). *Steels from* 35 *to* 50 *tons/sq. in.* Threads in these materials can easily be cut. Through-holes from ¼ in. up can be tapped by machine taps or single taps. It is advisable to give them a shaving chamfer (see Fig. 4) to remove the chips more easily. The chips are continuous, remain together and are pushed out in the direction of the cut in front of the tool point (see Fig. 14). If it is possible, the thread ought to have a sufficient run-out—as indicated in Fig. 32, even for blind holes, then this would allow

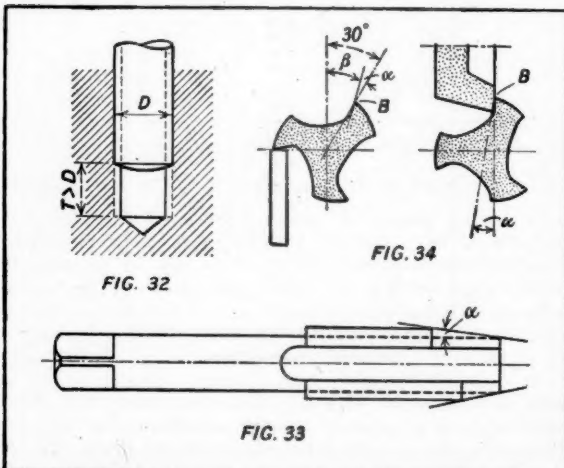


Fig. 32.—Recommended run-out for blind tapped hole.
Fig. 33.—Faulty tap with unsymmetrically ground chamfer.
Fig. 34.—Method of grinding a tap cutting edge B. For three and six-flute taps the angle $\beta = 30 - \alpha$ where α is the rake handle.

single taps to be used, but these should not have a shaving chamfer. If the run-out is too short, several taps of the set must be used. The designer may note that for blind holes a run-out or recess to two-pitch is necessary. Taps with spiral flutes—the direction of the helix—depends on whether the bore is blind or through (see Figs. 14 to 16) facilitate the removal of the chips in such cases. The angle of rake is 5 to 10°, the cutting speed approximately 50 ft./min.

Ample coolant and lubrication with good cutting oils are required. The machine tap for these steels ought to be made of high-speed steel with ground flanks. Mild steels below 35 tons/sq. in. are generally very tough ; they require cutting angles and tools similar to those in group No. 2 (tough-hard material).

Group (2). *Tough-hard materials.* The cutting speed is 3 to 12 ft./min., with ample coolant. Cutting angle 5 to 10°.

Group (3). *Cast iron.* For ordinary cast iron (140 to 160 Brinell hardness), the same taps are used as for ordinary steel. For through holes use machine taps of high-speed steel or a single tap. For harder cast iron (180 to 220 Brinell hardness) use the same taps as for rough hard material. The cutting angle is 0 to 5°. Cut dry or use tallow or a good cutting oil.

Group (4). *Brass and bronze* give the least difficulties in tapping. The thread is generally cut in one operation, using a machine tap or a single tap. Gun-nose taps are very suitable. (See Fig. 16). Cutting speed about 80 ft./min., cutting angle 0 to 5°, which can be increased to 10 to 15° if a gun-nose tap is used. Ample coolant with cutting oils.

Group (5). *Light metals* frequently cause difficulties in tapping. The alloys vary considerably and consequently great differences in machineability are found. The aluminium manganese alloys are tough. They clog easily and give long curls, the removal of which cause difficulties, and for this reason the flutes of the tap must be very wide in order to give ample chip space. Small taps have generally two flutes, otherwise three fluted taps are used (see Fig. 22). A front rake angle of 15 to 20° is suitable. A machine tap, however, must not be used for holes where the tap has to be reversed. The magnesium alloys give short broken chips ; therefore their removal is not difficult, but they dull the cutting edges considerably, as do the aluminium silicon alloys. The cutting speed should be about 100 ft./min. Some alloys ought to be tapped using no lubricant, e.g. electron. With others the coolant increases the quality of the finished thread. Fine threads below 0.03 in. pitch ought not to be used at all on these materials. Because great accuracy is usually required with light metals, ground taps are mostly used. The threads can be finished with one single tap, and to make

TABLE XIII.—MATERIALS, CUTTING SPEEDS, AND LUBRICANTS

MATERIAL	RESISTANCE	CUTTING SPEED		Coolant and lubricant	REMARKS
		High speed tap. Ft./mn.	Car. steel Ft./mn.		
Ordinary mild steel ...	35 to 40 tons/sq. in. ...	60 to 80	25 to 35	Soap water, soluble oils.	
Steel with 0.4 to 0.5C. ...	40 to 50 ,, ...	30 to 50	12 to 25		
Cr-Ni steels	60 to 70 ,, ...	20 to 25	6 to 12	Turpentine.	Tapping with a set of three taps (at least).
Heat-treated Cr-Ni steels .	80 to 90 ,, ...	6 to 12	3 to 6	Lard-oil, rape-seed oil.	
Cast iron Brinell hardness	110 (soft) Brinell ...	45 to 55	25 to 35	Cut dry or use tallow or a good cutting oil.	Plenty oil.
	150 (medium)	40 to 45	20 to 30		
	180 (fairly hard, machine tools).	30 to 40	12 to 20		
Brass	12 to 16 tons/sq. in....	80 to100	40 to 50	Soap water soluble oil.	
Bronze	16 to 25 ,, ...	65 to 80	25 to 40	Lard-oil.	
Aluminium and its alloys .	10 to 16 ,, ...	150 to200	100 to150	Soap spirit, kerosene mixture of kerosene and rape-seed oil.	
Elektron	10 to 18 tons/sq. in....	150 to200	100 to150	No lubricant or coolant.	

this possible it is advisable to have a long run-out. A gun nose tap with 6 thread chamfer is quite suitable.

Group (6). *Plastics* and pressed materials, e.g. Vulcan-fibre, bakelite, etc., can be cut with the same tools as those for light metals. The chips are generally coherent. The phenol resins behave in a similar way to cast iron, being brittle and giving short chips. The taps should have cutting angles from 0 to 5°. Pressed materials dull the cutting edges considerably. They should be cut dry to avoid spoiling the material itself, with cutting speeds of about 100 ft./min. The threads can be finished with machine nut taps or single taps.

Table XIII gives particulars of materials, cutting speeds and lubricants. Owing to the wearing qualities of these materials the relief should be a minimum say .0 to .0005 in. per land. The cutting angle must be a maximum and the tap kept sharp.

Maintenance of Taps.

Taps which are dull or which show a burr on the cutting edges ought to be reground immediately. Far more taps are broken by being used blunt than by other tapping faults such as too small tapping holes or inappropriate lubricants. Regrinding should be done as soon as the cutting edges are dull and on both the flute of the tap and on the back of the chamfer. Taps should only be reground on machines, because the height of the cutting edges of the chamfer must remain uniform and concentric to ensure a good cutting action. There are a good many special machines and attachments for use on grinding machines or lathes to allow a mechanical backing-off of the tap. Whenever possible, nuts and internal threads ought to be tapped on a machine to ensure that the thread is accurately cut. Taps which are used on machines and correctly maintained are very seldom broken, and maintenance of machine taps is considerably lower. Most drilling machines can be equipped to-day with tapping attachments built into the machine or else made as accessories. On large workpieces it is an advantage to be able to interchange the tap with the twist drill to avoid moving the work. By using a multiple drilling machine each spindle may be reserved for its special tool, so that tool changing is unnecessary and correct working speed is maintained.

The Regrinding of Chamfer and Flutes.

As has been stated previously, almost all the cutting work must be done by the teeth of the chamfer. The quality of the finished nut or internal thread depends almost entirely on the shape and sharpness of these teeth. Therefore regrinding should be done with the greatest care.

The angle of rake and the length of the chamfer must be the same for all edges. All cutting edges of the flutes must be on the surface of the cone, the axis of which must coincide with the axis of the tap and the cone must be of equal angle for all the cutting edges. Bell-shaped internal threads are cut when the chamfer is ground unevenly (Fig. 33). A tap of such a shape will cut mostly on the short chamfer, whereas the teeth on the long chamfer would cut little or not at all. Due to this one-sided action the tap is deflected

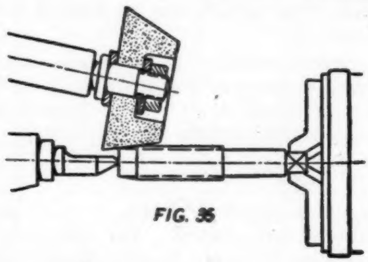


FIG. 35

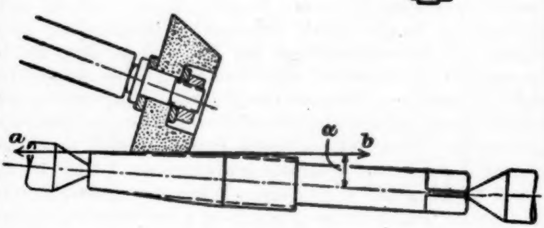


FIG. 36

Fig. 35.—Grinding tap chamfer by the plunge-cut method.
Fig. 36.—For grinding a long chamfer the tap must be traversed. The table is set at an angle ∝ = half the included chamfer angle.

and the oblique teeth have a reaming action which causes the bell-mouthed hole. Further the flute in front of the heaviest cutting tooth is easily plugged up. The one-sided stress plus the clogging in this flute causes the frequent breakage of the tap. All the necessary conditions for correct regrinding can never be fulfilled completely by doing it by hand. A well-designed grinding fixture or a grinding machine should be used which allows this otherwise difficult operation to be performed easily, accurately and cheaply.

The tap is best reground between centres. If there are no centre holes, e.g. when the tap has a broken shank, a good centring chuck

should be used. The first operation is to regrind the flutes of the tap (Fig. 34) until all damage to the cutting edges is eliminated. (For angle of rake see Fig. 24). The flutes must be accurately spaced by a division plate or some other adequate means. Then the chamfer is to be ground and the width of the grinding wheel must be such that the relatively short chamfer of the most frequently used hand taps and also of many special taps can be ground and backed-off by a plunge cut. The angle of the chamfer can be obtained by a simple inclination of the grinding spindle (Fig. 35).

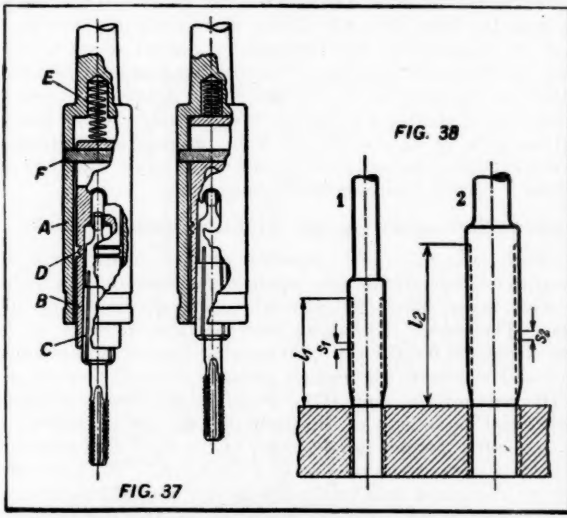


Fig. 37.—Rigidly centred chuck vith axial self-adjustment.
Fig. 38.—An example illustrating the use of the chuck in Fig. 37.

The grinding wheel is bevelled to increase the angle between the axis of the tap and the grinding spindle so that the fast and loose headstocks clear the main spindle bearing. The grinding wheel, however, will seldom be wide enough to regrind or back-off the essentially longer chamfers of machine taps. In such cases the tap must be traversed with the table adjusted to angle *a* in the direction of *a*, *b* (Fig. 36). Ample coolant must be used.

Chucking the tap.

It is of importance to secure the accurate axial position of the tap with regard to the machine spindle and to direct the chamfer truly in line with the axis of the hole to be tapped. A correct

chucking device secures not only the correct position of the tap but lengthens its life and produces good threads, avoiding any tendency to " reamer " the first part of the nut. Various tap shanks are shown in Fig. 21.

The perfect tap is spoilt unless it runs perfectly true and is truly in line with the bore. Customers who excel in tapping operations hold tap shanks within .0005 in. for size and concentricity with threads, in order that they may run true. A lot of trouble lies in using inferior tapping devices, chucks, etc. But the worst offender is the floating tap holder. There is no such thing ! If the tap is out of line with the hole, the only power that can bring that tap into line is to be supplied by the resistance the work offers to the tap entering the hole at an angle. This resistance cannot be effective until the tap has entered to a considerable depth and even then, when the axis of the tapped portion is at an angle to the hole axis, the tap has to be brought to its new lining-up position continuously, as the revolution of the machine spindle takes it out, and that under conditions if torque transmission is impossible.

Lengthwise Self-adjusting but Rigidly Centred Chuck.

The chuck, Fig. 37 (left), consists of two main parts which are lengthwise adjustable one against the other. An external sleeve with taper shank (A) is used to clamp the chuck in the machine. The sleeve (B) has an internal taper to take an intermediate chuck (C) for the tap. To equalise inaccurate alignment of the tool and the bore, the design permits a small floating of the sleeve (B) around the ring (D). Further, the design allows considerable axial movement of the parts one against the other to the extent of about 1.5 times the diameter of the tap. This axial movement is made against the tension of a spring (E). The cross pin (F) through an elongated hole in the sleeve (B) is used to prevent the sleeve from falling out. Fig. 37 (right) shows the total movement of the internal part in relation to the external sleeve by compressing the spring (E). The arrangement is useful for use in multiple spindle drilling machines in which several threads must be cut simultaneously and the taps do not all begin their cutting action at the same time.

As an example, Fig. 38 shows two nuts which are to be tapped with different pitches S_1 and S_2. Both spindles have the same number of revolutions.

To tap the full length, tap No. 1 needs a path of l_1 using $n=\frac{l_1}{S_1}$ revolutions. Tap No. 2 is taking path l_2 in the same time. $\therefore \frac{l_2}{l_1}=\frac{S_2}{S_1}$ and the difference between the lengths l_2-l_1

$= \frac{S_2 - S_1}{S_1} \times l_1$. This amount must always be smaller than the axial movement of sleeve (B).

Performance Tester for Taps.

Because a well-made tap (ground) should follow its pitch without external pressure, the rear flank of the tap takes the thrust to force the tap forward, and therefore the axial forces balance each other

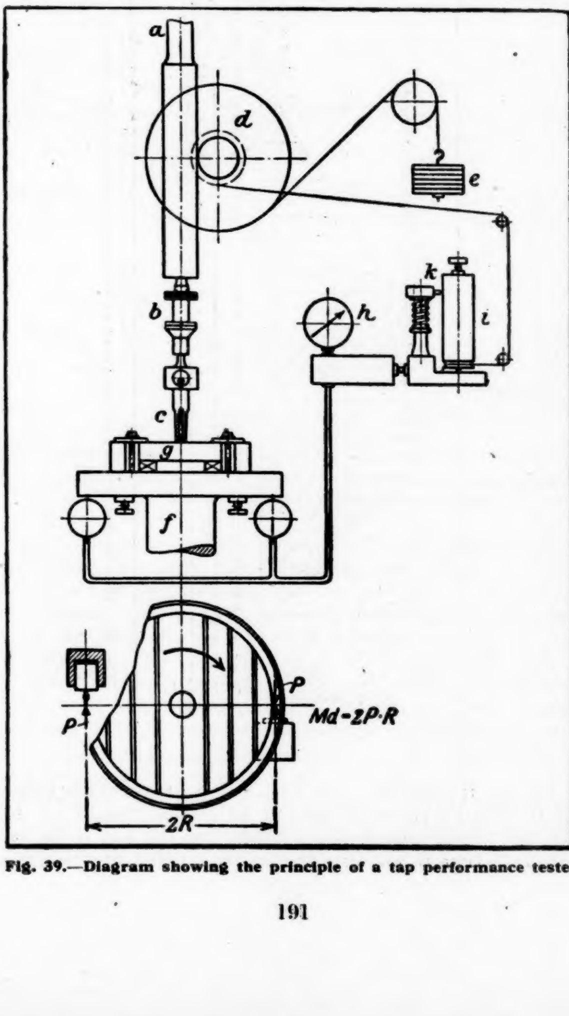


Fig. 39.—Diagram showing the principle of a tap performance tester.

on both symmetrical flanks of each thread tooth. Only the torque is effective and measureable. The tap performance tester is shown in Fig. 39 ; *a* is the spindle of a drilling machine, *b* is the centring

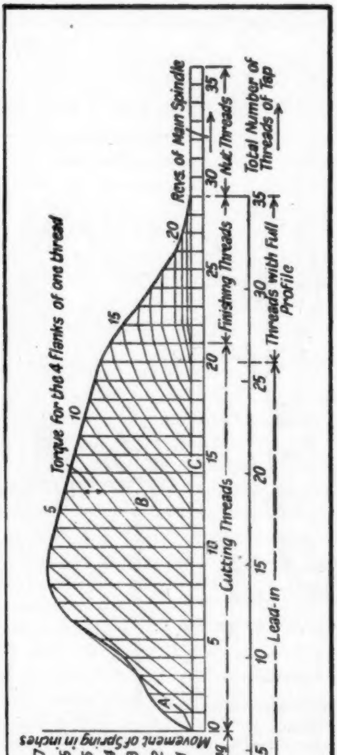


Fig. 40.—Distribution of work as measured by the torque on the cutting edges of a tap.

chuck for the tap shank, *c* the tap, *d* is a drum which causes the spindle to feed by the constant but adjustable weight *e*, *f* a table to take the torque reaction, *g* a holder for the nut to be tapped, *h* a pressure gauge to measure the torque created by the tangential

forces P, and i the recording drum. This drum is driven from the feed gear integral with d and thus ensuring that the drum i is turned in exact relation to the feeding-in motion of the tap. The pen k is actuated up and down corresponding to the variation of the turning moment $M_d = 2\,PR$, where R is the distance of the tangential forces P from the centre of the performance table.

A typical diagram taken with the performance tester is shown in Fig. 40. The torque in lb./ft. is shown vertically, the feed motion in number of threads (pitch) horizontally. The maximum torque

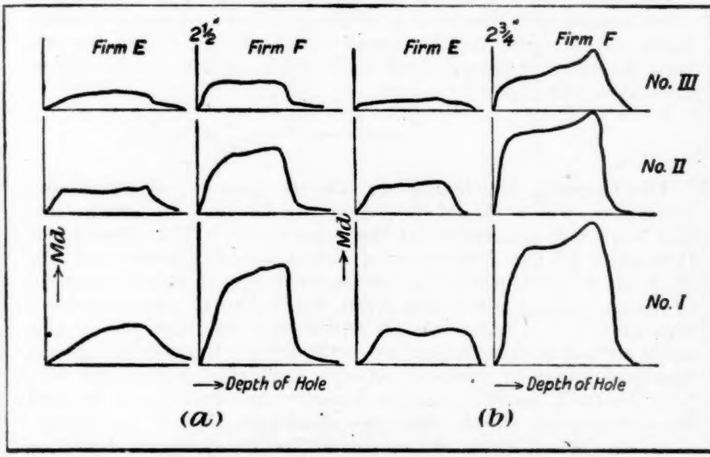


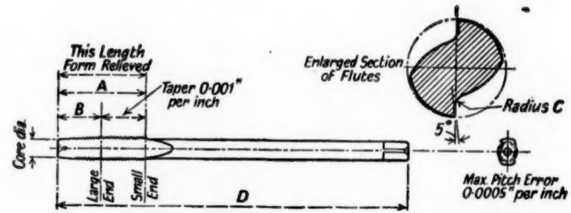
Fig. 41.—Results of tests on sets of taps by different makers showing good (a) and bad (b) load distribution when tapping cast iron.

of all four flanks is at the ninth thread. The progress of one pitch corresponds to one revolution of the spindle, therefore the horizontal divisions give at the same time the numbers of revolutions of the main spindle. After reaching the maximum the torque decreases almost to zero at the twenty-ninth revolution, only a friction load remaining. The cutting threads of the chamfer work from 0 to 21 and then the finishing threads are entered, but the cutting work is done by the chamfer only. Threads with full profile are working from 20 to 29 respectively (from 26 to 35 if the non-cutting part of the point in lower line is considered). The full profile teeth calibrate the nut only. If instead of one machine tap a set of three hand taps is to be used, the distribution of the cutting action between the three tools of one set should be chosen so that the taper tap does the biggest part of the cutting action. The second

(plug) should do approximately half of the work done by the taper and finishing almost the full profile with the exception of the last roughing. The third tap should be only calibrating. Fig. 41 compares two sets of three taps made by two different firms but used under the same circumstances. Fig. 41 (a) shows a good and Fig. 41 (b) a bad distribution of the loads, this being created by wrong grinding only. A good radial drill was almost destroyed by this wrongly ground set. After having the taps correctly reground, the tools worked to full satisfaction.

The methods of gauging the threads produced and the errors these gauging tests disclose, e.g. bell-mouth holes, reamered threads, holes out of round and not parallel with the axis, thin threads, torn threads and threads with poor finish—will be dealt with in another article.

The foregoing article has set out the general rules and considerations which should be remembered when designing taps. The work was undertaken at the request of the War Emergency Committee of the Institution of Production Engineers, and Mr. E. J. H. Jones-Southall has collaborated. As practical examples of the application of the data given, Figs. 42 to 47 show a series of taps which are in actual use. It will be seen that the rules already given are not always carried out to the letter. Even so, the last six examples given by courtesy of the Associated Equipment Co., Ltd., Southall, produce good work under the conditions given, and the tool designer should draw the conclusion that in tap design, as in any other branch of tool design, specific examples should be treated on their merits.



		A	B	C			
No	SIZE	Length of thread	Length of chamfer	Flute radius	Overall length	Tolerance on effec. dia.	USED FOR
1	1/4" B.S.F.	1 1/8"	21/32"	3/64"	4 3/8"	+ .0014" + .0013"	Copper tap passed through job, 6' per min., 13/64" drill.
2	1/2" B.S.F.	1 3/4"	7/8"	5/64"	7"	+ .0012" + .0013"	Soft steel, tap passed through job, 6' per min., 27/64" drill.

Fig. 42.—Two-flute nut taps of high speed steel, ground and form relieved, for machine tapping.

D

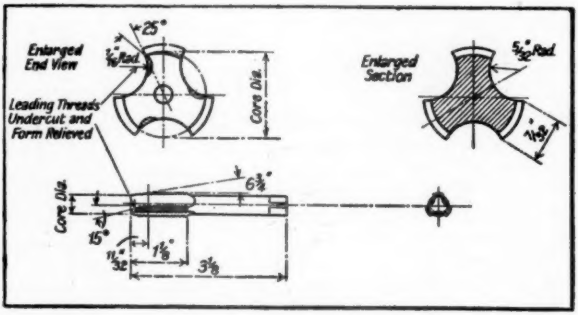
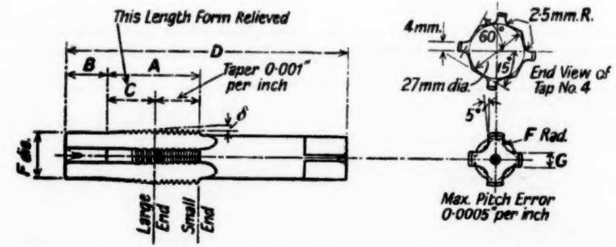
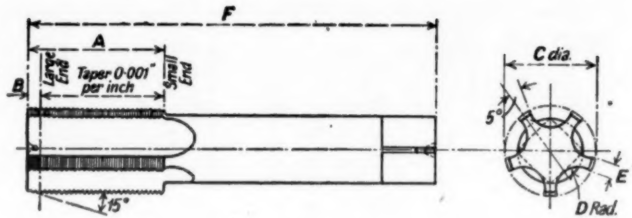


Fig. 43.—Three-flute B.S.F. hand tap of high-speed steel, ground and form relieved. It is intended for re-tapping by hand. The maximum pitch error is 0.0005 in. for inch, and the limits on the effective diameter 0.000 to 0.001 in.



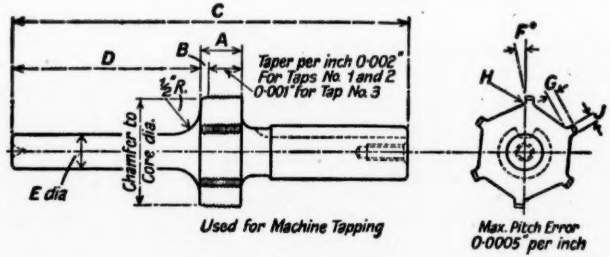
		A	B	C	D	E	F	G		δ	
No.	Size	Length of thread	Length of pilot	Length of chamfer	Overall length	Diam. of pilot	Radius of flute	Width of tooth	Tol. on effective diameter	Angle of chamfer	Used for
1	1/2" B.S.F. ...	1 13/16"	5/16"	1 1/16"	6 3/4"	.418"	1/8"	3/32"	+ .002" + .003"	2°	Ni Cr steel, 75 tons, tap passed through, 12' per min. .422 hole.
2	1" B.S.F.	1 13/16"	3/4"	23/32"	5 1/8"	.850"	7/32"	3/32"	+ .0012" + .0021"	4°	.35 carbon steel, tap passed through, 8' per min.
3	7/8" B.S.P., 1.189" dia., 14 T.P.I.	2 13/16"	5/16"	1 1/4"	5 13/16"	1.0987"	5/16"	3/32"	+ .0005" + .002"	3°	Elektron, tap revers ed out, 28' per min., 1 37/64" hole.
4	36 mm., 16 T.P.I. ...	1 1/2"	None	5/16"	4 1/2"	None	See drawing for end view		+.025mm +.062mm	12°	Cast iron, tap reversed out, 15' per min., 1 13/32" hole.

Fig. 44.—Four-flute taps of high-speed steel, ground and form relieved, for machine tapping.



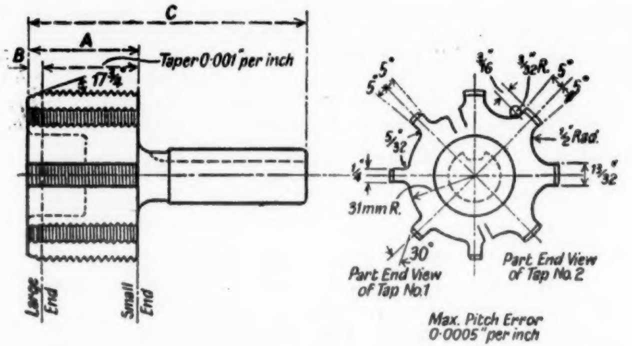
		A	B	C	D	E	F				
No.	Size	Length of thread	Length of chamfer	Overall dia.	Flute radius	Width of tooth	Overall length	Max'm pitch error	Tol. on effective dia.	Mater'l	Used for
1	43 mm., 12 T.P.I., roughing. L. hand.	2½"	mm. 6	mm. 42.62	mm. 10	mm. 6.5	7½"	.0005" per in.	+.037mm +.090mm	H.S. steel	.35" carbon steel tap reversed out, 13' per min., 1³⁷/₆₄" hole.
2	43 mm., 12 T.P.I., finishing, L. hand.	2½"	6	43.0	10	6.5	7½"	None allowed	+.075mm +.100mm	C. steel	As No. 1.
3	⅞" dia., 26 T.P.I. ...	1¼"	3/16"	⅞"	5/16"	3/16"	4¼"	.0005" per in.	+ .0005" + .002"	H.S. steel	3% Ni-Cr. steel, tap reversed out, 9' per min., .83" hole.

Fig. 45.—Five-flute taps for machine tapping. Taps (1) and (2) are ground and unrelieved, cutting three diameters deep. The rougher is undersize on all elements. Tap (3) is ground and form relieved.



		A	B	C	D	E	F	G	H	J		
No.	SIZE	Length of thread	Length of chamfer	Overall length	Length of pilot	Diam. of pilot	Rake angle	Depth of flute	Radius of flute	Width of tooth	Tol. on effective diam.	USED FOR
1	52" dia., 16 T.P.I. ...	3/4"	3/16"	7 1/4"	3 7/16"	mm. 16	0°	mm. 5	mm. 2.5	mm. 4	+ .03mm. + .01mm.	Cast iron tap reversed out 22' per min.
2	48" dia., 8 T.P.I. ...	1 1/2"	1/8"	4 5/16"	No pilot		5°	1/4"	7/32"	5/16"	+ .002" + .004"	Mall. iron tap reversed out 10' per min.
3	2.22" dia., 20 T.P.I. ...	1 1/4"	15/64"	5 9/32"	No pilot		5°	3/8"	1/8"	21/64"	Nom'l to + .001"	3% Ni-Cr. steel, tap pas'd thro. 25' per min.

Fig. 46.—Six-flute taps for machine tapping. Tap (1) is ground and unrelieved. Taps (2) and (3) are ground and form relieved.



		A	B	C		
No.	SIZE	Length of thread	Length of chamfer	Overall length	Toler'ce on effective diam.	
1	80 mm. dia., 8 T.P.I.	1¾"	¼"	4 13/16"	+ .06 mm. + .04 mm.	Aluminium, tap reversed out, 45′ per min., 2.995″ hole.
2	80 mm. dia., 8 T.P.I.	2"	¼"	5 1/16"	+ .06 mm. + .04 mm.	Elektron, tap reversed out, 66′ per min., 2.995″ hole.

Fig. 47.—Eight-flute taps for machine tapping, ground and form relieved.